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PHOTOGRAPHIC REMOTE SENSING TECHNIQUES FOR EROSION EVALUATIONS ON WILDLANDS

by Paul T. Tueller and
D. Terry Booth

A Final Report to the U.S. Department of the Interior
Bureau of Land Management Contract 08550-CT5-2

College of Agriculture
University of Nevada, Reno

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ABSTRACT

Numerous film types, bands, scales and color techniques were evaluated for erosion features. Large scale (1:600) 70mm vertical color aerial photography was found to be a practical method for taking inventory of erosion conditions on rangeland watersheds managed by the U.S. Department of the Interior, Bureau of Land Management. Photo evaluations on these large scale photographs were found to be as accurate and less costly than ground techniques. Small scale photographs (1:25,000 and smaller) are shown to be useful for mapping sites with similar erosion activity and potential, for planning erosion sampling on watersheds and for inventorying and measuring large erosion features over considerable land areas. Procedures are described.

ACKNOWLEDGEMENTS

This research was performed under the sponsorship and financial assistance of the U.S. Department of the Interior, Bureau of Land Management, Contract No. 08550-CT5-2. Work was conducted in the field in Nevada and at the Remote Sensing Laboratory, Max C. Fleischman College of Agriculture, University of Nevada, Reno. Appreciation is expressed to all those who assisted with data gathering and analysis or who may have provided ideas used in the completion of the study. Special thanks must go to Ron Kuhlman and Julian Anderson of the Bureau of Land Management and to Dr. Wilbert H. Blackburn of the University of Nevada, Reno.

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SUMMARY

This study was designed to determine the practicability of using vertical, aerial photography to inventory erosion conditions on arid and semiarid watersheds under the administration of the Bureau of Land Management and to provide guidelines for its use, if found to be useful. Coils Creek was chosen as the principal study site because of a wide variety of erosion conditions and due to the background of ground and photographic data already available.

A year of monitoring established erosion movement transects resulted in the assurance that large scale (1:600) 70mm sequential photography can be used to detect and estimate soil movement. Soil surface factors which lend themselves to evaluation of erosion from large scale aerial photography were selected as follows: flow patterns, wind erosion, litter movement, vesicular horizons, bare ground, rills and gullies. Ground observations were compared with photographic data to develop descriptions to identify and evaluate the erosion conditions using the above factors. Specific examples of each soil surface factor have been presented and the guidelines discussed relative to each. These guidelines were tested by five interpreters who used them to evaluate erosion on Coils Creek and Mount Sterling management units in Nevada. In order to compare these results with the evaluations given the same areas by Bureau of Land Management field crews, stereopairs were selected from the sample and accompanying evaluations tabulated

and compared with ground results. Caution must be used in drawing conclusions from this comparison since neither evaluation is known to be more correct than the other. However, the reasonably close agreement of the two evaluations was taken as an indication that the interpretation guidelines developed lead to evaluations that are at least as accurate as those currently being obtained on the ground. Costs involved in flight time over the watersheds and in making the evaluations were found to be $0.0158/ha ($0.0074/acre)for Coils Creek and $0.0047/ha ($0.0019/acre) for Mount Sterling. In every case costs were less than $0.025/ha ($0.01/acre).

Numerous other film types, bands, scales and color techniques were evaluated for erosion features. Intermediate scale photographs (1:25,000) were optimum for mapping sites with similar erosion activity or potential. Scales between 1:60,000 and 1:110,000 were found to be optimum for planning the sampling of rangeland watersheds as well as being suitable for mapping erosion features. Erosion features mappable from both small and intermediate scale photography fall in six categories: (1) erosion along and related to roads; (2) erosion along and related to streams or watercourses; (3) general eroded areas with considerable sheet, rill and gully erosion; (4) areas of bare ground caused by man's activities, e.g., mineral assessment work and water developments for livestock; (5) flooding; (6) areas with no obvious erosion features. Size of the erosion features detectable, varies from scale to scale. NASA high flight 1:500,000 and ERTS-1 (1:1,000,000) images were less useful although the inventory of large erosion features was facilitated over considerable land areas by these synoptic views. A matrix is presented to show the relative usefulness of the various film-filter-scale combinations.

Both Spatial Data Corporations Datacolor model 401/704 image enhancement system and International Imaging Systems' Model 600 Mini Addcoll color viewer were evaluated for this potential for automatic extraction of information concerning erosion features and to provide color enhancements as an aid to photo interpretation, respectively. It is unlikely that the color density slicing technique can be used to expedite the photo interpretation process for erosion evaluations on large scale imagery in the near future. However, the use of a color viewer for making specific enhancements shows promise for aiding in the routine analysis of small scale (1:60,000-1:110,000) imagery for identification and measurement of erosion features.

INTRODUCTION

The United States Department of the Interior, Bureau of Land Management (BLM) faces the problem of maintaining a current inventory of erosion conditions over approximately 65 million hectares (160 million acres) of public land. The inventory is necessary in order to evaluate present management systems and to determine their effectiveness in conserving the Soil resource. Present ground techniques are slow and subject to the following problems:

(1) Obtaining a representative sample - The selection of a repressentative sample is often biased by how accessible the area is by vehicle.

(2) The subjectiveness of the evaluations.

(3) Lack of permanent, objective record of range condition.

(4) Federal government personnel ceilings. This along with the rising cost of manpower, fuel for transportation, and cost due to wear on the vehicles used, are all combining to make ground methods increasingly expensive.

Aerial photographic techniques offer a fast, and more economical means of obtaining and updating an inventory. Vertical aerial photographs are not limited by ground accessibility, they allow an increased sample size at similar cost, provide a permanent record, and offer greater objectivity.

The objectives of the study are as follows:

1) To determine if large scale (1:600) 70mm color aerial photography could be used on a practical basis for erosion inventory.

2) To identify erosion features on both small and large scale aerial photographs.

3) To develop interpretation guidelines for erosion evaluations on vertical aerial photographs and to analyze the potential of using color density slicing and color enhancement techniques to aid in photo interpretation of erosion features on wildlands.

5) To describe procedures whereby such data can be gathered, analyzed and used.

LITERATURE REVIEW

Early Reference to Erosion

Mans awareness of accelerated erosion, and the environmental disasters that may accompany it, is not restricted to the twentieth century. Plato (427-347 B.C.) makes reference to the unhappy effects of uncontrolled erosion in his work, Critias, (Jowett, 1914). Crop rotation helped stabilize cultivated hillsides in seventeenth century England, and in the eighteenth century the use of broad wheeled wagons helped prevent gully erosion on agricultural lands (Bennett, 1939). In 1769 George Washington was experimenting to determine, " 'Whether the land was not preserved more by harrowing than by lying in furrows' " (Fitzpatrick, 1925, quoted from Hall, 1937). Jefferson sought to control erosion on his farm by contour furrowing (Burges, 1937) and Patrick Henry is reported to have said that, " 'since the achievement of our independence, he is the greatest patriot, who stops the most gullies' " (N.M., 1834, quoted from Hall, 1937).

Inventory of Erosion

The majority of references dealing with erosion inventory are concerned with erosion on agricultural lands. (U.S.D.A., 1938, U.S.D.A., 1951). Systems for the inventory of erosion on wildland watersheds appear to have developed partially from methods used to evaluate conditions and trend of range forage. Range condition and trend is concerned with the quality as well as the quantity of forage, whereas watershed

condition is concerned with the soil holding abilities of the vegetation. Jardine and Anderson (1919) list seventeen questions which should be answered in making a range inspection. They list several indicators of overgrazing, one of which was the amount of erosion and barreness to be found in an area; and state that a good range is also a good watershed. In 1937, Talbot listed several vegetative characteristics, along with the amount of erosion, as important in determining condition and trend. Humphrey and Lister (1914) found a correlation between range condition (as indicated by vegetative cover) and the amount of soil loss and runoff. They suggested that range condition classes provided a basis for watershed management. Ellison and Croft (1944) firmly established evaluation of erosion as an important prerequisite for determining condition and trend. They described range indicators important in erosion evaluation: 1) the quantity and distribution of litter; 2) quantity and distribution of bare soil; 3) observed soil movement (including sheet erosion); 4) soil remnants and pedestals; 5) accelerated erosion pavement; 6) gullies and rills; 7) blowouts; 8) wind deposits and 9) alluvial deposits. Others have included these indicators of erosion as important considerations in determining condition and trend (Sampson, 1952; Stoddard and Smith, 1955). Sharpe (1938) added puddling of soil, exposed roots, frost heaving, the process of headcutting in gullies, and mass movement (including "cattle terraces" or sheep paths on hillsides) to the list of erosion indicators. Gleason, (1953) in an excellent discussion of erosion indicators on California watersheds, added the following to the list: 1) sheet, gully and rill erosion; 2) plant and litter cover; 3) bare

soil; 4) pedestals and soil remnants; 5) erosion pavement and other surface rock; 6) blowouts and wind deposited soil; and 7) alluvial deposits (U.S.D.A., 1959; U.S.D.I., 1973).

Large Scale Aerial Photography to Evaluate Erosion

Large scale aerial photography has been found to be economical and well suited to the analysis of range vegetation (Driscoll and Reppert, 1968; Lorain, 1970; Carneggie, 1968). The technology for large scale (1:600) photography has been largely developed and has been successfully used in studies of vegetation of the range, forest and production agriculture (Aldrich, et al, 1959; Aldrich, 1966; Avery, 1968; Carneggie and Reppert, 1969; Guitjens and Mahannah, 1972). Carneggie (1968) observed that the analysis of soil surface conditions such as rockiness, surface texture, litter, and erosion disturbances were among the potential uses of 70mm photography. Changes in soil type, the presence of surface gravels, cow droppings, and sand dunes (Carneggie, et al. 1971) could be detected from the photography. They found that litter was generally easier to detect on color infrared film; but noted that while soil surface features were about equally visible on color and color infrared film, color film gave a more representative picture.

Lorain (1970) observed litter, rocks, erosion features and animal trails on large scale photography. White rocks from 2.5 to 5.0 cm (1 to 2 inches) and larger were seen at a scale of 1:728. Wind erosion was inferred when plants growing on hummocks (coppice dunes) were detected.

Studies of pocket gopher (Thomomys talpoides) activity have shown that counts of gopher mounds made from large scale aerial photographs (1:600) were 97% as accurate as ground surveys (Driscoll, et al. 1972).

Small Scale

The use of small scale aerial photography to evaluate erosion features has been little investigated. According to Morrison and Cooley (1973a) ERT-S-7 MSS images can be used to indicate the extent of flooding and the areas affected by severe sediment deposition and erosion along a river. Band 5 was found to best display areas of sand and gravel deposition. They were also able to detect a widening of river channel deposits when pre and post images were compared. Morrison and Cooley (1973b) found that in evaluating the usefulness of ERTS-7 for identifying and mapping accelerated erosion in southern Arizona that the red MSS band gave the sharpest definition of modern arroyos. Band 7 was found to be the most useful in identifying the more erodible soils in the late fall and winter images. Tanguay, et al (1969) found that the red band was most useful for soil studies.

Seevers and Drew (1973) suggest that a potential soil erodability could be inferred through ERTS-7 color composits of the 4, 5, 7 bands. They also believe that ERTS imagery will provide a means for monitoring erosion problems in areas that are over-grazed or burned by range fires.

Poole (1969) was able to identify through the use of Ektachrome and Ektachrome infrared, slope failure forms at scales of 1/6,000,

1/26,000 and 1/48,000. The types of slope failure noted were erosional forms of sheet wash, rill wash, and gullying which result from sheet or channelized overland flow and mass wastage forms of creep, flow, slide, and fall which result from gravitational movement. In addition, Poole (1969) indicates that the most suitable small scale photography for slope failure studies should be at a scale of 1/20,000 to ensure recognition and positive identification of erosional phenomena and mass wastage forms.

STUDY SITE LOCATIONS AND DESCRIPTIONS

Primary Study Site

Coils Creek Watershed and Adjacent Areas

The Coils Creek watershed is located in Eureka County, Nevada, the major portion of it being in Township 23 North, Range 49 East M.D.P.M. The western boundary of the watershed is the Simpson Park Mountains, the east is the Red Hills, part of the Roberts Mountains. The headquarters of the 3-Bar Ranch are within the watershed.

The basin is in the Battle Mountain District of the Bureau of Land Management and consists of about 12,430 hectares (48 square miles) of public domain except for some private land owned by the 3-Bar Ranch (Blackburn, et al. 1969). The altitude of the highest peak is around 2700 meters (8,880 feet): the basin outlet is near 1980 meters (6,500 feet) soils are derived mainly from quartzite, slate, basalt and alluvium with some sandstone, dolomite and shale also present. Streams within the basin are ephemeral, originating mainly from snowmelt or thunder storms. Several perennial springs are found in the watershed. Valley drainage is to the south, into Kobeh Valley. The climate is semi-arid with a four-year annual precipitation average of 29.7 cm (11.7 inches). November is the month with the highest average precipitation, 6.1 cm (2.4 inches), with December, April, June, July and September being next, all with about 2.5 cm (1 inch) each. The northern desert shrub and pinyon-juniper are the two vegetative zones represented in the watershed.

Secondary Study Sites

Hallelujah Junction

A single transect was located 8 km (5 miles) north of Hallelujah Junction, California, along Highway U.S. 395. The altitude is 1487 meters (4800 feet) in juniper (Juniperus osteosperma) woodland. The site contains most soil surface factors that were studied, including well developed vesicular horizons.

Mount Sterling

In addition to the Coils Creek watershed, a second watershed was chosen to test procedures and interpretive abilities. The Mount Sterling management unit is located at the north end of the Spring Mountains in southern Nevada. The Spring Mountains have a northwest orientation with drainage into Mercury Valley and Indian Springs Valley in the north and Pahrump Valley and the Amargosa Desert on the north and west. Pinyon-juniper (Pinus monophylla/Juniperus osteosperma) woodlands occupy the higher mountains, southern desert shrub (Yucca schidigera, Ambrosia dumosa, Coleogyne ramosissima) vegetation occupies the lower elevations. The unit is 46,749 hectares (180 square miles) in size.

Hercules Gap

A third watershed was sampled and used to test procedures. This watershed is located in White Pine County, Nevada, a few miles north of the town of Ely. This area drains south and east to Hercules Gap and then into Steptoe Valley. Pinyon-juniper woodlands occupy higher elevations with big sagebrush, meadow and white sage (Eurotia lanata) standing below. The unit is 10,624 hectares (41 sq. miles) in size.

PROCEDURES

In order to meet the overall objectives, the answers to the following questions were sought:

1) Can the soil surface factors used by BLM (soil movement, surface litter, surface rock, pedestalling, flow patterns, rills and gullies) be evaluated from large scale (1:600 - 1:1000) vertical aerial photography? If so how will the photo interpretation criteria differ from the ground criteria (See appendix 2, p. 59)?

2) Can small scale images from ERTS-1 (1:1,000,000) and NASA high flights (1:60,000-1:500,000) provide useful information concerning erosion on wildlands (See page 33)?

3) Does multiband photography provide additional information concerning erosion features (See Table 7, page 36)?

4) What is the best scale, film-filter combination, and time of year for making these evaluations (See Table 7, page 36)?

5) Are there other soil surface factors (than those used by BLM) which should be used? Can the amount of soil deposited or removed be measured on sequential photography? (See Appendix 2, apge 59)?

6) What is the level of interpreter experience needed in making erosion evaluation from photographs of various scales and types (See page 27, soil movement evaluations)?

7) Do additive color viewing and density slicing techniques offer potential for automatic photo analysis of erosional features (See page 40)?

Acquisition of Ground Data

Soil surface data gathered by BLM personnel were used to locate seven different transect sites to be closely studied in or near Coils Creek watershed (See Table 1). Each transect site at Coils Creek consisted of an aerial photo transect, marked at each end with ground markers[1] to direct the pilot and to determine photo scale of the resulting photographs and a conjunctive 30.45 meters (100 foot) transect for ground data acquisition. The 30.45 meter transect was marked by steel fence posts on each end, and by steel bars driven into the ground at the 0 and 30.45 meter marks.

At each of the 30.45 meter transects, soil surface (elevation) profile data were gathered using an automatic level and staff. Readings were made at changes in the soil surface profile (that is, at edges and bottom of rills, depressions, and other irregular soil patterns). If no abrupt elevation change was evident, readings were made at regular intervals of .305 or .610 meters (1 or 2 feet). Subsequent profiles were made by taking readings at the original points along each transect. Regression analysis was used to compare sequential data to evaluate changes occuring during the intervening time, and an analysis of variance was used to measure the variation occuring along the transect line at the time the measurements were made. The more rills and gullies encountered, the higher the resulting coefficient of variation.

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[1]An example of the ground markers can be seen in Fig. 10 on page 76. They are made of .64 cm (.25 inch) plywood and painted white. The large marker .61 x 1.22 m (2 ft x 4 ft) is attached to a steel fence post driven into the ground at an angle. The small markers are 61 x 15 cm (24 x 6 in) with a 5 cm (2 in) black strip through the center lengthwise.

Table 1.

Table I. Erosion Measurement Transects at Coils Creek

Name of Transect	Location	Altitude	Slope	Exposure	Vegetation
Jackass Canyon	Red Hills	2091 meters (6860 ft.)	40%	S	Pinus monophylla/Juniperus osteosperma, Artemisia tridentata
Meadow	Simpson Park Mountains	2390 meters (7575 ft.)	5%	E	Iris missouriensis, Taraxacum officinale, Poa sp.
Ranch Flat	Valley Bottom Near 3-Bar Ranch	2035 meters (6675 ft.)	flat	—	Artemisia arbuscula
Ranch Hillside	West slope of Red Hills near 3-Bar Ranch	2042 meters (6700 ft.)	49%	W	Pinus monophylla/Juniperus osteosperma,
Roberts Creek	Kobeh Valley about 3 miles southeast of the Roberts Creek Ranch	1950 meters (6400 ft.)	5%	S	Artemisia tridentata, Artemisia arbuscula
Simpson Park II	Simpson Park Mountains	2461 meters (8075 ft.)	35%	N	Artemisia tridentata with a good cover of forbes, mostly Wyethia mollis
Tonkin Summit	Red Hills	2240 meters (7350 ft.)	8%	NW	Artemisia tridentata, Artemisia arbuscula

Acquisition of Photographic Data

One of the most important reasons for choosing the Coils Creek watershed was because of the considerable photographic data available of the area. Coils Creek has served as a test site on three other projects sponsored by the EROS Program of the Geological Survey, NASA and the Nevada Agricultural Experiment Station, respectively. As a result photography from numerous film types, scales and data could be analyzed (Table 2).

Two Hulcher 70mm, Model 103 rapid sequence cameras were operated simultaneously to obtain large scale (1:600-1:12,000) color and color infrared photography of each site studied. The cameras are 23 x 23 x 18 cm (9x9x7 inches) in size and weigh about 4.5 kg (11 lbs.) without film. A 150 mm (6 in) Schneider-Xenotar F 2.8 lens was used on each camera. Power for each camera was provided by a 12-volt battery. The photography was obtained from a Cessna 206 equipped with an 18" camera hatch. With the plane flying about 161km per hour (100 mph) the cameras were pulsed at 5 frames per second in order to obtain 60% overlap for 1:600 scale stereo coverage for each two frames on either film type. Several other scales (1:1000 and larger) were obtained with both film types.

Flights over the Coils Creek transects were made in the fall of 1972, and in the spring, summer and fall of 1973. A flight to sample the entire Coils Creek watershed was made in June, 1973. Flights over the Hallelujah Junction transect were made in spring, summer and fall 1973. Mount Sterling management unit was photographically sampled in February 1974.

Table 2. Source, Scale, Type, Format and Date of Imagery Reviewed for Erosion Features on the Coils Creek Watershed, Nevada

COILS CREEK

Source	Scale	Type	Format	Date
NASA	1:60,000 Zeiss	Color IR	9½ "	10/21/71
I²S	1:62,000 Zeiss	B&W Multi.4 Band	9½ "	6/22/71
I²S	1:25,000	Color IR	9½ "	6/22/71
NASA	1:110,000	Color Pos.	9½ "	10/21/71
NASA	1:110,000	Color Pos.	9½ "	10/21/71
NASA	1:110,000	Color IR	9½ "	10/21/71
NASA	1:110,000	Color IR	9½ "	10/21/71
NASA	1:60,000 Zeiss	Color IR	9½ "	10/21/71
RSL	1:600	2443 CIR	70 mm	7/1/74
NASA	1:450,000	Color IR	70 mm	10/21/71
NASA	1:450,000	B&W Blue Band	70 mm	10/21/71
NASA	1:450,000	B&W Red Band	70 mm	10/21/71
NASA	1:450,000	B&W Green Band	70 mm	10/21/71
NASA	1:450,000	Color IR	70 mm	10/21/71
NASA	1:450,000	B&W Blue Band	70 mm	10/21/71
NASA	1:450,000	B&W IR Band	70 mm	10/21/71
NASA	1:1 mil.	Thermal IR	70 mm	10/21/71
RSL	1:1000	CIR 2443	70 mm	5/10/73
RSL	1:600 (random sample)	CIR 2443	70 mm	6/29/73
RSL	1:800-1:12,000	Color 2448	70 mm	10/16/72
RSL	1:600 (random sample)	Color 2448	70 mm	6/29/73
RSL	1:600	Color 2448	70 mm	7/1/74
RSL	1:800	Color 2448	70 mm	8/24/73
RSL	1:800, 1:400	Color 2448	70 mm	?
RSL	1:700	2443 CIR	70 mm	6/19/73
RSL	1:10,000 1:1,000	Color IR	70 mm	8/17/72
RSL	1:700, 1:1200	Color 2448	70 mm	6/19/73
RSL	1:10,000, 1,000	Color 2448	70 mm	8/17/72
NASA	1:450,000	Color	70 mm	10/21/71
NASA	1:450,000	B&W Red	70 mm	10/21/71
NASA	1:450,000	Color	70 mm	10/21/71
RSL	1:600	Color IR	70 mm	6/5/73
RSL	1:800-1:12,000	Color IR	70 mm	10/16/72
RSL	1:800-1:400	Color 2448	70 mm	6/5/73

Table 2. (continued)

COILS CREEK

Source	Scale	Type	Format	Date
NASA	1:450,000	B&W IR	70 mm	10/21/71
NASA	1:450,000	B&W Green	70 mm	10/21/71
NASA	1:1 mile	Thermal IR	70 mm	10/21/71
RSL	HJ 1:600	Color 2448	70 mm	6/18/73
BLM	1:15,840	Pan. B&W	9½ "	6/22/65 6/23/65 7/16/66 6/22/65
ERTS-1	1:1,000,000	Color Composite 4, 5, and 7		6/11/73
ERTS-1	1:1,000,000	B&W 4 Bands		Several Dates Between 7/72 and 11/73

NASA - National Aeronautics and Space Administration Aircraft Program Underflights - Flights were conducted either from Houston with the RB57-F aircraft or the U-2 aircraft from Moffett Field, California 1:110,000.

RSL - Remote Sending Laboratory, University of Nevada, Reno, 70 mm Hulcher 103 rapid sequence cameras.

I^2S - Data obtained by International Imaging Systems, Mountain View, California with their 4-lens camera.

BLM - 1:15,840 Black and White Panchromatic coverage provided by the Nevada State Office, Bureau of Land Management.

ERTS-1 - Provided from the Earth Resources Technology Satellite from NASA's Goddard Flight Center, Greenbelt, Maryland.

Photo Interpretation

Development of Guidelines for Large Scale Interpretation

Photographic data from the several transects were compared with ground data and soil surface factors were selected which appeared to be the most valuable in determining erosion condition class. The development of guidelines to aid in the identification and interpretation of the selected soil surface factors from vertical aerial photographs (stereopairs) required setting down observations and ideas on paper, reviewing these with project and BLM personnel and then rewriting them in an effort to make the guidelines useful on a practical basis.

Testing Guidelines

Interpretation tests were designed and used to evaluate the guidelines developed. These tests consisted of evaluating erosion conditions on 10 positive print examples, where the ground conditions were known to the investigator plus 5 in which the conditions were not known. Adjustments were made to the guidelines in view of the results.

The final test consisted of using the guidelines in an evaluation of positive transparency samples of the entire Coils Creek watershed (103 stereopairs). The evaluation was made by the author and by students who have worked on BLM field crews. A record of the time and costs for photographing and evaluating the watersheds was kept.

The evaluations obtained from the photography were compared with the ratings given these same areas by BLM field crews. In order to make the comparisons, each stereopair was classified as to vegetative

Photo Interpretation

Development of Guidelines for Large Scale Interpretation

Photographic data from the several transects were compared with ground data and soil surface factors were selected which appeared to be the most valuable in determining erosion condition class. The development of guidelines to aid in the identification and interpretation of the selected soil surface factors from vertical aerial photographs (stereopairs) required setting down observations and ideas on paper, reviewing these with project and BLM personnel and then rewriting them in an effort to make the guidelines useful on a practical basis.

Testing Guidelines

Interpretation tests were designed and used to evaluate the guidelines developed. These tests consisted of evaluating erosion conditions on 10 positive print examples, where the ground conditions were known to the investigator plus 5 in which the conditions were not known. Adjustments were made to the guidelines in view of the results.

The final test consisted of using the guidelines in an evaluation of positive transparency samples of the entire Soils Creek watershed (103 stereopairs). The evaluation was made by the author and by students who have worked on BLM field crews. A record of the time and costs for photographing and evaluating the watersheds was kept.

The evaluations obtained from the photography were compared with the ratings given these same areas by BLM field crews. In order to make the comparisons, each stereopair was classified as to negative

subtype (s)[2] and exposure(s). From the total sample, of each watershed, stereopairs were selected which represented each of the plant communities listed by the ground crews. The previously made erosion evaluations were then totaled and summarized.

The students making the erosion evaluations from the photography were given no special training or instructions other than those found under Appendix 2, entitled Interpretation Guidelines. All but one had worked with BLM ground crews doing erosion evaluations, and all had very little experience with photo interpretation. It should be recognized also that BLM ground crews vary considerably in experience.

The comparisons made do not constitute a statistically valid comparison of the ground evaluations versus the aerial method since each watershed has been evaluated only once on the ground, and by different field crews. The ground evaluations would have to be repeated several times before a sound comparison could be made. However, the comparisons do give an indication of the utility of the aerial photography and of the interpretation guidelines developed.

Estimating Rill and Gully Depths

To test the feasibility of quantifying erosion using large scale photography, a Bausch and Lomb Stereoscope and an Abrams stereometer (height finder) calibrated in hundredths of a millimeter were used to estimate the depths of rills and gullies from 70mm color transparencies on a scale of 1:625. Photo measurements were compared with measurements obtained from the field (See results, pg.24).

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[2]The subtypes usedare the same as used by BLM (Manual Section 7322). Plant communities refer to the combined subtype (aspect) and exposure.

Development of Guidelines for Small Scale Interpretation

Travel to Coils Creek for examination and measurement of ground features along the large scale transects provided the opportunity to note larger erosion features for evaluation on the small scale photographs (see Table 2.). All of the small scale frames of Coils Creek (1:25,000-1:1,000,000) were systematically evaluated by carefully examining each film type and writing descriptive notes of the erosion features observed and found to be measurable.

As each film type was reviewed, the following criteria were considered:

1) Erosion along roads due to water cutting, gully formation, double roads because of temporarily unpassable stretches (e.g. high waters). This included gullies moving away from the roads.
2) Erosion along streams such as bank cutting, new meanders (changes of stream course), collapse of banks indicating undercutting and removal of vegetation along the stream channel due to flooding along the stream.
3) General eroded areas with considerable sheet, rill and gully erosion. These areas usually appear lighter in color and are sparser in vegetation indicating probable removal of top soil.
4) Areas of bareground or nearly so caused by man's activities either directly or indirectly.
   a) Mineral assessment sites with probable erosion.
   b) Cleared areas around dwellings.

c) Water developments with vegetation removal differentially having considerable bare ground near the water source and greater vegetation generally coinciding with concentric circles radiating outward from the source.

d) Livestock driveways

e) Recent and sometimes older wildfire scars.

5) Soil movement with or without vegetation removal over large areas as a result of flooding (see example, Fig. 4).

6) Areas with no obvious erosion features observable on small scale imaging (1:25,000 and smaller).

Each image type was evaluated on a scale of 0-5. If a frame had no obvious use a 0 or no use rating was given. If all the first five criteria could be evaluated, at least to some relative extent, on the frame then a rating of 5 or excellent was given. If 3 or 4 of these criteria could be noted, a rating of good was given, for 2 a rating of fair and 1 a rating of poor. Time and funds available precluded a more detailed quantitative analysis of the small scale imagery.

During the evaluation process attempts were made to map areas of similar erosion and erosion potential. One map of single frame at 1:25,000 was prepared as an example in this report. Also consideration was given to the difficult proposition of coupling the detailed information extracted from large scale photographs to small scale photography. Mapping areas of similar erosion or erosion potential over a considerable acreage based on data from the 70 mm large scale imagery constitutes the best procedure for this.

Color Enhancement Techniques

To evaluate the potential for automatic photo analysis of erosional areas, a Spatial Data Systems, Inc. model 401/704 Data-Color Image Enhancement System was used to analyze 10 separate 70mm frames. In terms of the percent of the frame, an effort was made to quantify the following factors on large scale 70mm images: 1) vegetation and interspace; 2) vesicular horizons; 3) cattle trails; 4) rills; 5) ant hills; 6) litter; 7) surface rock; 8) flow patterns; 9) gullies; and 10) bare ground.

A Model 600 color additive viewer manufactured by International Imaging Systems, Mountain View California, was used to evaluate erosion features on I^2S 4-lens imagery (Scale 1:62,000) from a flight conducted over Coils Creek on June 22, 1971. Color and color infrared were simulated on the receiver as well as a variety of other color renditions. Each was evaluated for the ease of identifying various erosion features.

RESULTS AND DISCUSSION

Large Scale Soil Movement Detected by Soil Surface Profile

A comparison of our early May 1973 photography with Fall 1972 photography, indicated considerable soil movement. Changes in the mountain meadow transect (see Fig. 14 on page83) consisted of head-cutting by the gully and the forming of a small channel in an adjacent cow trail. Spring runoff also deposited a large amount of debris (gravel, silt, litter) on the meadow above the gully. Subsequent field checking disclosed that much of this material came from a road above the meadow.

At other transects a general sloughing had filled or partially filled most of the rills. This was particularly noticeable on film coverage of the transect located on the hillside adjacent to the 3-Bar Ranch (Ranch Hillside transect) (Fig. 12 page81). Data collected at this site agree with the conclusions made from studying the photography. A regression analysis of the data (Table 3) collected at the site in Fall 1972 against data collected in Spring 1973 gives a correlation coefficient of .83. An analysis of varience of these two groups of data gives a coefficient of variation[3] of 36% for the fall,

[3]Coefficient of variation is the sample standard deviation expressed as a percentage of the sample mean. It is a relative measure of variation.

but only 31% for the spring, suggesting the profile was more level, i.e., less variation in the spring profile.

At the Roberts Creek Transect, a general fluffing of soil was noticeable on the photographs, but no real movement was seen. Here the fall and spring data had a correlation coefficient of 0.99. In the analysis of variance, the spring data again had the lower coefficient of variations, but there was only 1.8% difference between fall and spring.

The third and last transect from which data was gathered during Fall 1972 was the Jackass Canyon transect. The area is in very poor condition, and erosion has left the hillside heavily covered with an unstable erosion pavement and larger surface rock. The regression analysis of fall against spring again gave a coefficient of 0.99. The analysis of variance showed a 2% increase in variation between fall and spring. This minor change was not detected on the photography.

In a comparison of Spring 1973 data against Fall 1973 data, regression analysis for all transects was equal to 0.99. In comparing analysis of variance only two Coils Creek transects showed more than a 0.4% change. Ranch Hillside had a 1.6% drop in variation, which indicates that over the summer the sluffing in of rills continued. Rain which did fall was not in sufficient quantity or intensity to renew rill erosion. The other transect to show a change was Jackass Canyon, which had a 1.9% decrease in variation.

The Hallelujah Junction study site consisted of three 9.1 meters (30 feet) transects within the aerial transect. The 9.1 meter transects

Table 3. Correlation coefficients comparing soil surface profiles between dates and coefficients of variation for each site and date.[a)]

	No. of Variates	Correlation Coefficients Fall 1972 vs Spring 1973	Spring 1973 vs Fall 1973	Coefficient of Variation Fall 1972 C.V.	Spring 1973 C.V.	Fall 1973 C.V.
Jackass Canyon	78	r=0.99**	r=0.99**	39.0	41.0	39.1
Meadow	87		r=0.99**		31.2	31.5
Ranch Flat	69		r=0.99**		24.9	25.2
Ranch Hillside	60	r=0.83**		35.5	31.2	
	123		r=0.99**		73.5	71.9
Roberts Creek	81	r=0.99**	r=0.99**	54.0	52.2	52.6
Simpson Park	92		r=0.99**		65.1	65.3
Tonkin Summit	59		r=0.99**		46.0	46.0
Hallelujah Junction		May vs June	June vs August	May	June	August
1	24	r=0.99**	r=0.99**	43.4	41.7	43.7
2	23	r=0.99**	r=0.99**	17.9	18.0	21.5
3	34	r=0.99**	r=0.99**	45.9	44.8	44.9

a) ** indicates significance at 0.01 level of probability

Table 3. Correlation coefficients comparing soil surface profiles between dates and coefficients of variation for each site and date.a)

	No. of Variates	Correlation Coefficients		Coefficient of Variation		
		Fall 1972 vs Spring 1973	Spring 1973 vs Fall 1973	Fall 1972 C.V.	Spring 1973 C.V.	Fall 1973 C.V.
Jacques Canyon	70	r=0.99**		39.0	41.0	39.1
Meadow	87	r=0.99**			31.2	31.5
Ranch Flat	69	r=0.99**			24.9	25.2
Ranch Hillside	60	r=0.89**		35.5	31.2*	
	123		r=0.99**		25.5	21.9
Roberts Creek	81	r=0.99**	r=0.99**	54.0	32.2	32.6
Sipsey Park	92	r=0.99**			65.1	65.3
Tonkin Summit	33	r=0.99**			46.0	46.0
Wellington Junction		May vs June	June vs August	May	June	August
1	24	r=0.99**	r=0.99**	43.4	41.7	43.7
2	83	r=0.99**	r=0.99**	17.9	18.0	21.5
3	34	r=0.99**	r=0.99**	45.5	46.8	44.9

a) ** Indicates significance at 0.01 level of probability

were located at the bottom, mid-way up, and just below the crest of a hill. Data was collected in May, In June after a good rain and in August. Correlation coefficient for all transects were 0.99 for May against June and for June against August. Coefficients of variation changed about 1 to 2% with no consistant pattern of change evident. Again these changes were not detected on the photography.

Depths of individual rills and gullies were estimated within 13 cm (5 inches) of the actual depth with a stereometer (height finder). Errors tended to be compensating, resulting in a mean error of about 8 cm (3 inches). Such estimates lack the precision needed for rills, but are useful for large gullies.

The Interpretation Guidelines stand apart from the rest of this report and are therefore presented in Appendix 2. Because the guidelines represent the results of the major part of the research effort and the accomplishment of a chief objective, a brief summary is provided here. The reader should keep in mind that the guidelines are the result of an effort to develop methods for the interpretation of 70 mm aerial photography by BLM personnel for watershed evaluation, and that the guidelines were used in making the comparison of aerial and ground interpretation discussed in the next section.

The interpretation guidelines explain the limitations and possibilities associated with making erosion evaluations from the large scale photography. Erosion, erosional terms and the soil surface factors used are defined and explained. The soil surface factors found best for use with aerial photographs are: 1) flow patterns - which are used to evaluate sheet erosion; 2) wind erosion; 3) litter

movement; 4) percent bare ground; 5) percent vesicular horizons; 6) rill erosion and 7) gully and stream channel erosion. A rating scale has been developed and explained for each soil surface factor and each factor is illustrated by at least one stereopair example. It was found that careful construction of definitions and the use of numerous examples was necessary so that people involved would have somewhat the same understanding of erosion and how to identify and evaluate it.

Comparison of Aerial and Ground Interpretations

Results of Sampling Missions

Technical Problems. Besides testing general procedure, two important developments resulted from the actual sampling of the watersheds. First was the realization that flight lines must be planned so that abrupt changes of altitude are as few as possible. Flight lines which (for example) cross rather than parallel or circumnavigate mountain tops result in drastic changes in photo scale, photo scales which are too small, and loss of time when the plane must circle to gain altitude. Careful planning can usually avoid these problems.

It was found that a specialized intervalometer[4] was needed which

[4]The intervalometer included the following: 1)switches and timer so that two Hulcher 103 cameras could be operated singly or together to expose one stereopair each by pushing one button, 2)switches so that the camera could expose a single frame each or run continuously, 3)red lights to indicate camera operation, 4)the system was designed so that an additional timer could be installed, which would automatically time the interval between exposure of the stereopair-thus eliminating the need for a stop watch, and leaving the photographer free to take notes, make camera adjustments and/or change film in an alternate camera. Such a system would also aid in more exactly locating each stereopair, since human error (usually due to the necessity of accomplishing the above mentioned tasks between the photographic points) often results in errors of the time interval between exposures.

would allow the camera operator to take stereopairs only, rather than a series of 4 to 8 continuous frames at each sample point. An intervalometer meeting these needs was built for the project by B.M.H. Company Inc., 224 Vassar Street, Reno, Nevada, for the cost of $250.00.

Without the special intervalometer, 103 different sites were photographed at Coils Creek with 29 meters (95 feet) of film. At Mount Sterling 180 different sites were photographed using the intervalometer and the same amount of film.

Interpretation Tests Results. In comparing the results of BLM field crew evaluations with the evaluations from the aerial photography, consideration must be given to a basic difference between the methods. The ground evaluation must of necessity be based on the selection and evaluation of a representative area. The aerial method can theoretically yield a sample large enough from which to draw valid conclusions, and is not dependent upon the selection of representative areas.

It will be noted that in the case of Coils Creek, the results of the two methods of evaluation are very close (Table 4), the most notable differences being in the Artemisia arbuscula subtype with a north exposure and the Pinus monophylla - Juniperus osteoperma subtype with west exposure.

Mount Sterling ratings from the photography appear to be high (See Table 5). This indicates that a closer look should be given

to the evaluation of bare ground, especially with relation to surface rock.[5]

Factors Involved in Aerial Evaluation of Soil Movement

Factors which significantly affect the evaluation of erosion from aerial photographs include the photo scale, contrast, the degree of soil movement and the experience of the photointerpreter.

In order to accurately evaluate low condition class erosion, photographs must have a scale near 1:600 and have good contrast. The criteria for judging erosion from photos is much the same as evaluating erosion on the ground. The interpreter must have the following abilities a) a knowledge of erosion as it appears on the ground, b) an ability to see stereo, and c) an ability to give attention to small details such as photo texture, minor color changes, shape, shadow and pattern or spaitial arrangement. All of these skills are the result of experience and practice.

There are several steps which should be taken to help insure accuracy of aerial evaluations. The photointerpreter should spend an average of 3 to 5 min on each stereopair. This will mean that up to 10 min might be spent in careful examination of some of the stereopairs of each plant community, in order to ascertain general conditions.

A novice interpreter should begin using the stereoscope for only 0.5 hr at a time and increase viewing time daily. This will

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[5]Surface rock is the major soil protecting factor in the desert vegetation types of the Mount Sterling Management Unit.

Table 4.

Summary and Comparison of Erosion Evaluations of Coils Creek

Plant Community	Number of Samples[a]	Range SSF Rating	Mean SSF Rating	Erosion Condition Class
Artemisia tridentata West Exposure				
Ground Crew	4	27-50	38	slight
Photo Interpreters	6		24	slight
1		11-33	22	slight
2		11-37	23	slight
3		18-49	28	slight
4		9-30	17	slight
5		10-45	27	slight
Artemisia tridentata East Exposure				
Ground Crew	2	32-33	32	slight
Photo Interpreters	4		29	slight
1		19-34	27	slight
2		21-48	34	slight
3		15-34	25	slight
4		23-43	31	slight
5		17-38	26	slight
Artemisia tridentata Flat Exposure				
Ground Crew	1		29	slight
Photo Interpreters	7		23	slight
1		5-36	26	slight
2		11-38	23	slight
3		10-32	21	slight
4		11-46	25	slight
5		10-36	21	slight

a) Number of samples refers to transects used by the single BLM ground crew in their evaluation and the stereopairs used by the five photo interpreters.

Table 4.
(continued)

Plant Community	Number of Samples a)	Range SSF Rating	Mean SSF Rating	Erosion Condition Class
Artemisia arbuscula North Exposure				
Ground Crew	1		15	stable
Photo Interpreters	4		30	slight
1		19-47	31	slight
2		33-37	34	slight
3		19-38	29	slight
4		18-33	27	slight
5		28-31	30	slight
Artemisia arbuscula East Exposure				
Ground Crew	5	23-38	33	slight
Photo Interpreters	7		23	slight
1		15-33	26	slight
2		12-31	22	slight
3		12-33	18	slight
4		14-35	24	slight
5		15-39	25	slight
Pinus monophylla Juniperus osteosperma West Exposure				
Ground Crew	2	41-48	45	moderate
Photo Interpreters	9		37	slight
1		24-61	37	slight
2		27-51	39	slight
3		18-45	30	slight
4		32-47	38	slight
5		29-47	41	moderate

Table 5. Summary and Comparison of Erosion Evaluations of Mount Sterling

	No. of transects of stereo-pairs	Range SSF rating	Mean SSF rating	Erosion condition class
Cowania stansburiana - North Exposure				
Ground Crew	1		40	slight
Photo Interpreters	3		29	slight
1		13-14	13	stable
2		11-33	20	stable
3		25-42	34	slight
4		15-39	29	slight
5		33-64	48	moderate
Pinus monophylla - Juniperus osteoperma - North Exposure				
Ground Crew	3	25-27	26	slight
Photo Interpreters	4		26	slight
1		14-26	20	stable
2		15-27	20	stable
3		16-26	21	slight
4		29-41	37	slight
5		28-41	35	slight
Pinus monophylla - Juniperus osteosperma - South Exposure				
Ground Crew	1		27	slight
Photo Interpreters	9		32	slight
1		12-36	18	stable
2		13-35	20	stable
3		24-55	39	slight
4		22-59	39	slight
5		26-63	44	moderate

[1](10 stereopairs could not be evaluated due to snow cover)

Table 5. (continued)

	No. of transects of stereo-pairs	Range SSF rating	Mean SSF rating	Erosion condition class
Larrea tridentata - West Exposure				
Ground Crew	4	12-36	22	slight
Photo Interpreters	27		49	moderate
1		28-47	35	slight
2		24-66	49	moderate
3		30-62	48	moderate
4		34-61	52	moderate
5		46-74	62	critical
Larrea tridentata - East Exposure				
Ground Crew	3	35-49	40	slight
Photo Interpreters	11		47	moderate
1		29-49	34	slight
2		17-56	42	moderate
3		32-58	45	moderate
4		42-59	51	moderate
5		48-71	59	moderate
Other Desert Shrubs[1] - West Exposure				
Ground Crew	5	18-47	33	slight
Photo Interpreters	42		40	slight
1		15-52	32	slight
2		12-51	31	slight
3		21-60	40	slight
4		32-71	49	moderate
5		29-72	50	moderate
Other Desert Shrubs[1] - North Exposure				
Ground Crew	8	14-53	31	slight
Photo Interpreters	16		44	moderate
1		27-51	36	slight
2		18-51	36	slight
3		29-60	45	moderate
4		46-61	52	moderate
5		30-67	51	moderate

[1] *Yucca schidigera*, *Ambrosia dumosa*, *Coleogyne ramosissima*

Table 5. (continued)

	No. of transects of stereo-pairs	Range SSF rating	Mean SSF rating	Erosion condition class
Other Desert Shrubs - East Exposure				
Ground Crew	1		40	slight
Photo Interpreters	5		34	slight
1		11-37	25	slight
2		11-27	20	stable
3		26-49	37	slight
4		18-52	37	slight
5		45-71	52	moderate

allow the new interpreter to become accustomed to the use of the stereoscope without undue eye fatigue.

Erosion evaluations should be limited to two to three hours each day for any one interpreter. This practice will also help prevent eye fatigue, but more importantly, it will help prevent the interpretation work from becoming uninteresting or monotonous, a condition which leads to hasty evaluations and decreased reliability of data. This situation, no doubt, accounts for a large part of the variability seen in the results of the Mount Sterling test evaluations.

Economic Evaluation

An estimate of the probable cost for sampling and evaluation of the Coils Creek and the Mount Sterling watersheds has been made. Only costs involved in flight time over the watershed and in the interpretation of the film for erosion evaluation are included in the analysis (Table 6).

Small Scale

The foregoing along with the information provided in Appendix 2 firmly establishes the utility of large scale 70 mm photography (1:600 optimum) for erosion evaluations on Wildlands. While smaller scale photography will not allow the observation and measurement of small features such as rill erosion and litter dams between brush plants, there is great potential for assessing certain large erosion features over considerable acreage in a short time.

The imagery examined in this study varies considerably with respect to the capability of identifying and measuring erosion features. A film-

Table 6

Summary of Costs

	Item	Coils Creek	Mount Sterling
1.	Size of the watershed	12,430 ha (26,680 a)	46,749 ha (115,520 a)
2.	Flight time over the watershed	1 hr	1 hr 20 min
3.	Cost of plane and pilot	$60.00	$80.00
4.	Estimated cost of photographer and navigator (GS 11 and GS 9)	$13.00	$17.00
5.	Amount of film used	29 m (95 ft)	29 m (95 ft)
6.	Cost of film and development	$95.00	$95.00
7.	Handling time of transparencies (to number stereopairs and file rolls - ½ hr)	$2.00	$2.00
8.	Number of stereopairs evaluated	103	170
9.	Average time to evaluate one stereopair	4 min	2.4 min
10.	Time to evaluate entire watershed (item #1)	7 hr	7 hr
11.	Cost to evaluate watershed (GS 5)	$27.00	$27.00
12.	Total cost	$197.00	$221.00
13.	Cost per hectare	$0.0158	$0.0047
14.	Cost per acre	$0.0074	$0.0019

scale-bond matrix depicts the relative usefullness of each imagery type (Table 7). Those results generally show that as representative fraction scale decreases, the usefullness increases within limits. Also fake color composites tend to be rated higher but not in all cases. The relative usefullness of large, medium, intermediate, small and very small scale imagery are described as follows:

a. Large scale (1:600-1:1200) - This imagery has been discussed earlier and in Appendix 2 and will not be discussed here other than to indicate that nearly every kind of erosion feature can be evaluated.

b. Medium scale (1:1,000-1:10,000) - These scales were found to be particularly good for delineation of larger erosion flow patterns, drainages, and gullies. Vegetation types and densities were obvious. Depositional areas were identifiable and with a limited amount of field work areas of similar erosional ratings may be delineated and mapped. All criteria considered for the small scale evaluation were easily identified and measured and a rating of 5 was given in each case (Table 7).

c. Intermediate scale (1:25,000) - This particular scale was evaluated as a color infrared positive transparency. An excellent rating (5) was also given for this film type. This scale and film type is near optimum for mapping both vegetation and areas with similar erosion potential.

d. Small scale (1:60,000-1:110,000)- On this photography the larger gullies and drainages were visible and relative width and depth can be determined. Erosion caused by mining and road building

Table 7. Film scale-band matrix depicting the usefullness of various imagery types for erosion evaluations on wildlands.

	B&W Blue Band	B&W Red Band	B&W IR	B&W Green Band	Color Pos.	Color IR	Color 4,5,7 Composite	Thermal IR	B&W Print	Diaz-achrome
70 mm 1:1,000 or larger	--	--	--	--	5*	5*	--	--	--	--
70 mm 1:10,000-1:1,000	--	--	--	--	5*	5*	--	--	--	--
BLM 1:15,840	--	--	--	--	--	--	--	--	3-4	--
Color IR 1:25,000	--	--	--	--	--	5	--	--	--	--
NASA 1:60,000	--	--	--	--	--	4	--	--	--	--
I^2S 1:62,000	3	3	3	2	--	--	4	--	--	--
NASA 1:110,000	--	--	--	--	4	4	--	--	--	--
NASA 70 mm 1:450,000	1	2	1	1	3	3	--	--	--	--
ERTS-7 1:1,000,000	1	2	1	0	1	--	2	0	2	1
NASA 70 mm 1:1,000,000	1	2	1	0	--	--	2	0	--	--

-- No Data Available.

* Added to matrix for completeness. These scales are excellent for erosion evaluations although their coverage is naturally limited

was easily detectable. Erosional intensities themselves were not detectable, but relationships may be made with features such as vegetation sparsity, steepness of slope, direction of slope, vegetation types, etc. that correlate directly to the degree of erosional activity. It is still possible to accurately map areas of similar erosion potential or activity (Fig. 1). This mapping was accomplished with relative ease on each of these scales when color or color IR was used. The individual bands evaluated at a scale of 1:62,000 (I^2S) were only intermediate in their value for erosion evaluations. Most of these bands received an average rating (Table 7). Figures 2 and 3 show an example of a frame of 1:60,000 NASA High Flight Color IR mapped for erosion potential.

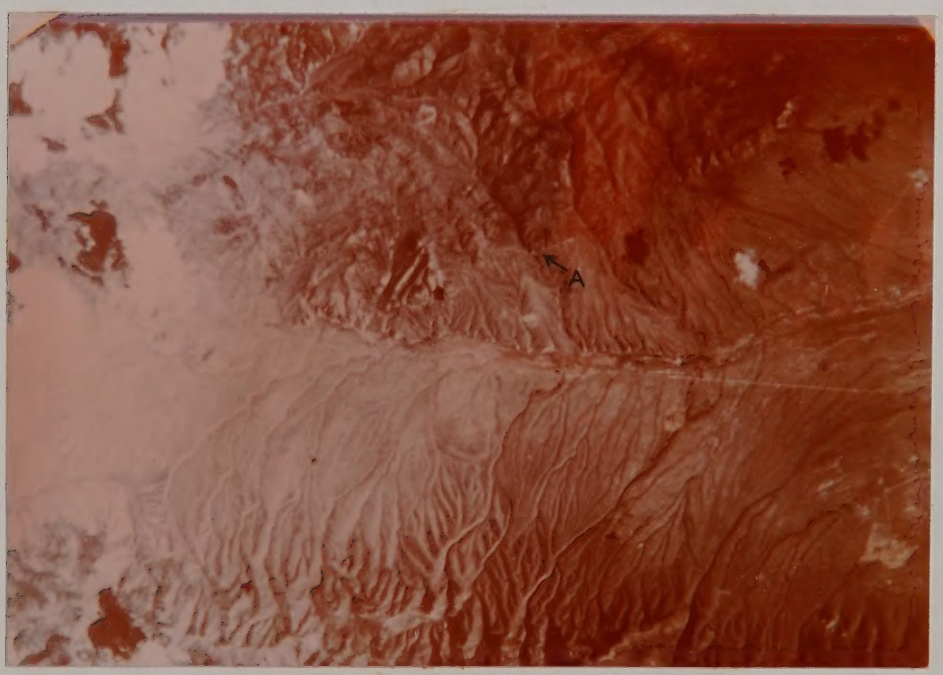


Fig. 1. Note the erosion along roads, streams and on areas of mining assessment (Point A). NASA High Flight 1:110,000 Color Infrared.

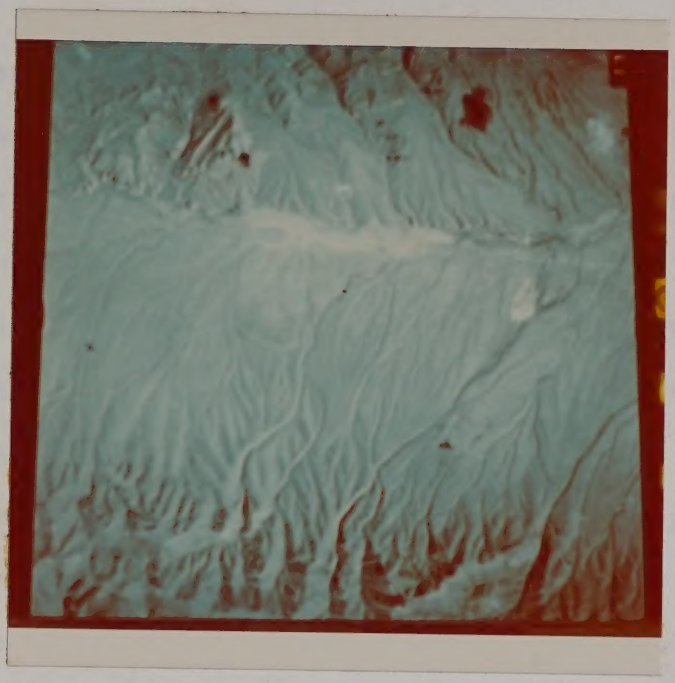


Fig. 2. NASA High Flight Color Infrared (1:60,000) frame found useful for mapping of areas with known erosion potential or activity.

Fig. 3. Overlay prepared for the 1:60,000 scale frame above depicting the mapping of areas with similar erosion potential or activity. For reference to numbers, see page 18.

These small scale photographs (1:60,000-1:110,000) offer good to excellent potential for mapping erosion potential and excellent potential as a means of planning for the proper subsampling of a watershed. A single frame of small scale NASA high flight imagery constitutes the best source for planning more detailed analysis of a watershed for purposes of erosion evaluation.

e. Very small scale (1:450,000) - At this scale, only the larger and more obvious drainages were visible and depth evaluation was not possible on the gullies and stream channels. Mining activity was still observed and evaluation possible. Only the more obvious vegetation types were identified with individual plants not detectable (except larger trees that are widely spaced). Meandering streams and areas with considerable cutting along the channel were identified.

f. Satellite imagery (1:1 million) - ERTS-1 color composites (NASA 4, 5, 7 band and Diazochrome) were viewed for their potential for erosion evaluations. Only a few of the more obvious drainages were visable. General vegetation types (meadow, northern desert shrub, pinyon-juniper, etc.) were detectable. General landforms (bajadas, alluvial fans, valley fills, etc.) were also detectable and the sequential nature of the ERTS-1 data offers potential for erosion monitoring. Depositional areas on playas were visible and offer additional erosion input. The true value of ERTS data for erosion evaluation is its ability to relate detailed erosional features

(available from larger scales) to the widespread drainage courses (some 50 or more miles long). Phenomena visible on ERTS-1 (standing water in playas, newly formed alluvial fans, or stream channels, recent deposition, etc.) are indications of widespread erosional conditions on the upper watersheds. Individual storm events can often erode areas large enough that they are observable on this imagery. Runoff from convective summer storms can be recorded on ERTS-1 imagery (Fig. 4).

Analysis of the Potential for Color Enhancement Techniques

Indications are that there is no immediate potential for automatic photo interpretation of soil surface features on large scale photography using color density slicing. The reasons for this are:

1. It is impossible to expose each succeeding frame under exactly the same light conditions as the frame before.
2. Different objects in a wild-land scene often photograph with similar densities, resulting in confusion when analyzed by density alone.

The Spatial Data Corporation's Datacolor model 401/704 does offer potential for expediting the photo interpretation process. Percent vegetation or percent bare ground can be determined quickly and accurately. The system contains a Density Profiler which provides a graphic display of film density along a vertical cross-section of the picture. This allows the photo interpreter to quickly decide which areas of the frame are of similar density and therefore which are of interest. An electronic planimeter allows an instantaneous digital read out in terms of percent area of the scene.

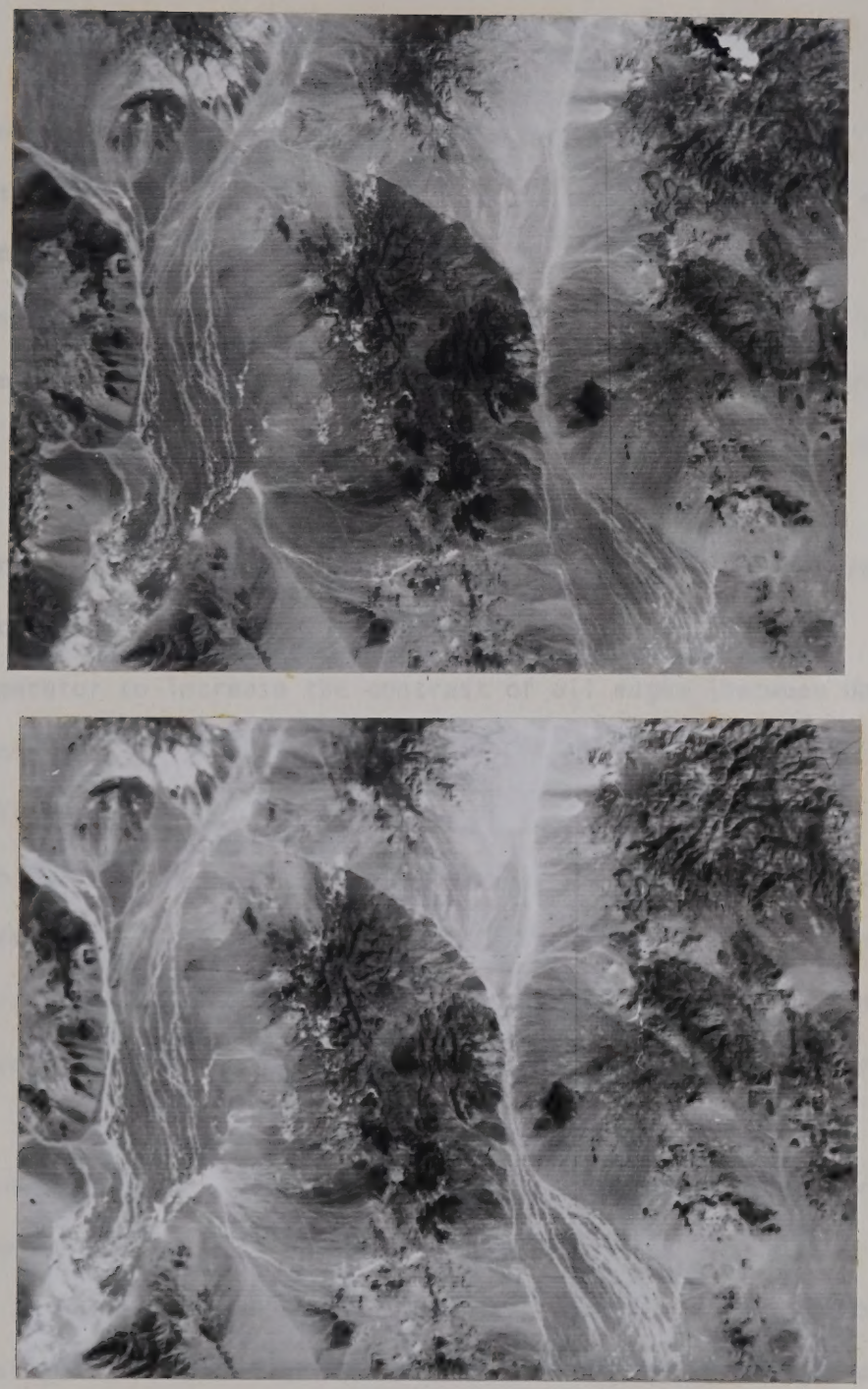


Fig. 4. Portions of MSS 6 band frames of central Nevada taken on August 10 (top) and September 15, 1972 (bottom). Area shown is approximately 52 by 38 miles and includes the community of Tonopah in the lower center, the San Antonio Mountains, Ralston Valley on the east and southern Big Smokey Valley to the west. Results of flash flooding between the two dates can be seen in Ralston Valley and on the alluvial fans on the west side of the San Antonio Mountains.

Such photo interpretations are of course dependent upon the ability of the machine to assign a discrete density level to a specific factor which is to be quantified.

Problems arise when different factors possess similar or identical film densities. This problem was especially noticed in the case where shadows fell across more than one factor, such as vegetation and bare ground.

There are several ways of solving this problem. One method which deserves special note is the Edge Enhancement system. This system allows the operator to increase the contrast of all edges (between density variations) until a single tone of grey provides background for a skeletal outline of all density variations found in the scene.

Although the problem of density confusion can be partially overcome by making careful adjustments and zooming the lens in on a small scene within the frame; if such adjustments are necessary for each frame analyzed; the photo interpretation process would be more time consuming than present methods.

We evaluated the 1:62,000 I^2S four-lens photography on the International Imaging Systems' Model 600 Mini Addcoll viewer. This machine allows true color, color IR and numerous other color enhancements to be displayed in near perfect registry with relatively little effort. However, the data must be obtained with the I^2S camera or some other similar camera that allows four filter combinations on a single film.

We found that it would have been useful if a means had been provided for viewing frame numbers. They could not be seen while in the strip machine making it difficult to reference location while using the viewer.

With experience it appears that certain color enhancements offer greater potential for erosion evaluations than any single black and white band or the true color or color infrared simulations (Fig. 5). Certain specific color enhancements, e.g., a green filter on red band, blue filters on the blue and green bands, and a clear filter on the black and white infrared band adds considerably to the capability of measuring erosion features (gullies primarily) in the meadow environment at Coils Creek (Fig. 6). An additional false color enhancement characterized by projecting the infrared band through a red filter, the red and green bands through a blue filter and the blue band through a clear filter was useful for enhancing erosion along the stream channel and along roads (Fig. 7). These useful color enhancements suggest that color multispectral viewing offers good potential for increasing the use of interpreting many erosion features on small scale photographic images. There seems to be less need for special color enhancements when evaluating erosion on large scale photography.

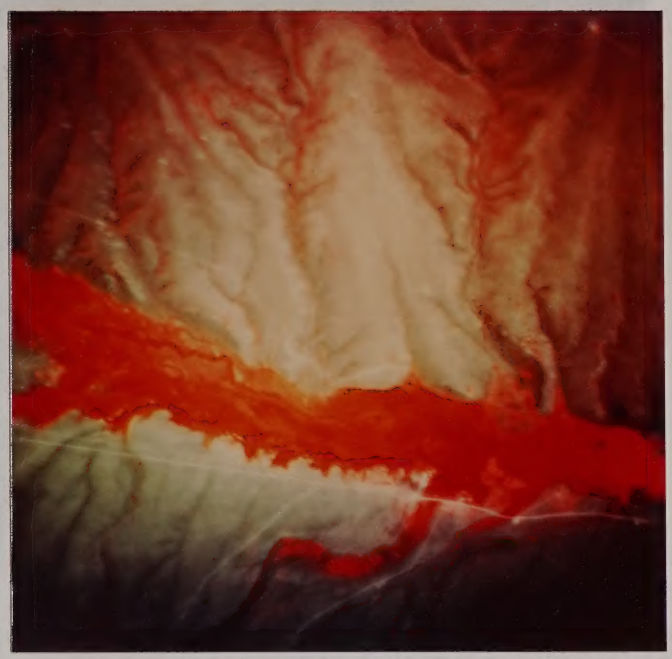


Fig. 5. A color infrared simulation of the Coils Creek meadow area (1:62,000 scale). Much of the erosion in the meadow is not seen.

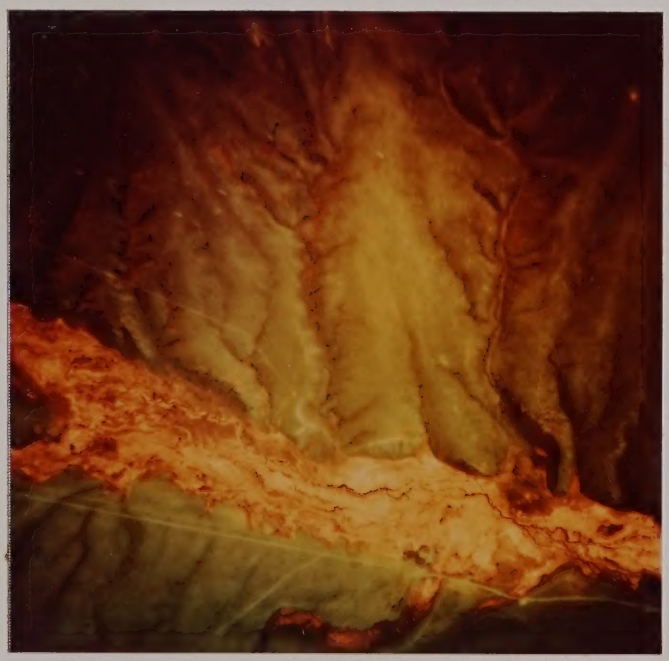


Fig. 6. This false color image greatly improves the ability of identifying and measuring erosion features in the Coils Creek meadow.

Fig. 7. Coils Creek. Erosion along the stream and roads was seen easier with an enhancement like this (original scale 1:62,000).

LITERATURE CITED

Aldrich, R.C., W.F. Bailey and R.C. Heller. 1959. Large scale 70 mm color photography techniques and equipment and their application to a forest sampling problem. Photogram. Eng. 25:747-754.

Aldrich, R.C. 1966. Forestry applications of 70 mm color. Photogram. Eng. 32:802-810.

Anderson, E.W. 1973. Acreage increase due to slope. J. of Range Manage. 25:316.

Avery, T.E. 1968. Interpretation of aerial photographs. 2nd Ed. Burgess Pub. Co. Minneapolis, Minn. 321 p.

Bennett, H.H. 1939. Soil conservations. McGraw-Hill Book Co. New York. 993 p.

Blackburn, W.H. R.E. Eckert, Jr., and P.T. Tueller. 1969. Vegetation and soils of the Coils Creek watershed. Nev. Agr. Exp. Sta. Bull. R48. 80 p.

Blackburn, W.H. 1973. Infiltration rate and sediment production of selected plant communities and soils in five rangelands in Nevada. Nev. Agr. Exp. Sta. Bull. R92. 99 p.

Branson, F.A., G.F. Gifford, and J.R. Owen. 1972. Rangeland hydrology. Soc. for Range Manage. Range Sci. Ser. No. 1. 84 pg.

Buckman, H.O. and N.C. Brady. 1969. The nature and properties of soils. 7th Ed. The Macmillian Co. New York. 631 p.

Burges, A.E. 1937. Soil erosion control. T.E. Smith and Co. Atlanta, Georgia. 187 p.

Carneggie, D.M. 1968. Applying remote sensing technology for improving range inventories. Proc. 5th Symposium on Remote Sensing of Environment. The Univ. of Mich. p. 373-385.

Carneggie, D.M. and J.N. Reppert. 1969. Large scale 70 mm aerial color photography. Photogram. Eng. 35:249-257.

Carneggie, D.M., D.G. Wilcox and R.B. Hacker. 1971. The use of large scale aerial photographs in the evaluation of western Australian rangelands. Dep. of Agr. West Australia, Tec. Bull. 10.

Driscoll, R.S. and J.N. Reppert. 1968. The identification and quantification of plant species, communities, and other resource features in herbland and shrubland environments from large scale aerial photography. Rocky Mountain Forest and Range Exp. Sta. U.S. Dep. Agr. (Forest Service).

Driscoll, R.S. and R.E. Francis. 1972. Multistage, multiband and sequential imagery to identify and quantify non-forest vegetation resources. Rocky Mountain Forest and Range Exp. Sta. U.S. Dep. Agr. (Forest Service).

Ellison, L. and A.R. Croft. 1944. Principles and indicators for judging condition and trend of high range watersheds. Intermountain Forest and Range Exp. Sta. Res. Pap. 6.

Edelson, E. 1973. Gaudy new ways to see things you cannot see. Smithsonian. 4:22-26.

Gleason, C.H. 1953. Indicators of erosion on watershed land in California. Transactions, American Geophysical Union. 34:3

Guitjens, J.C. and C.M. Mahannah. 1972. Airplane and film offer many advantages in remote sensing. Nev. Ranch and Home Rev. 4:7-9.

Hall, A.R. 1937. Early erosion control practices in Virginia. U.S. Dep. Agr. Misc. Pub. 246.

Hewitt, G.B., E.W. Huddleston, J.R. Lavigne, D.N. Uecker, and J.G. Watts. 1974. Rangeland entomology. Range Sci. Ser. No. 2. Soc. for Range Manage. Denver, Colorado.

Humphrey, R.R. and R.B. Lister. 1941. Native vegetation as a criterian for determining correct range management and run-off characteristics of grasslands. J. of Forestry. 39:837-842.

Jardine, J.T. and M. Anderson. 1919. Range Management on the national forests. U.S. Dep. Agr. Bull. 790.

Jowett, Benjamin. 1914. The dialogues of Plato. Vol. 4. Hearst's International Library Co. Inc. 208 p.

Lorain, G.E. 1970. 70 mm large scale aerial photography for range resources evaluation. MS Thesis. Univ. of Nev.-Reno. 93 p.

McNamee, M.A. and E.A. Kinne. 1967. Pasture and range fences. Dep. Agr. Mountain States Regional Pub. No. 2R.

Melton, F.A. 1940. A tentative classification of sand dunes - its application to dune history in the southern high plains. J. of Geology. 48:113-174.

Miller, D.E. 1971. Formation of vesicular structure in soil. Soil Sci. Soc. Amer. Proc. 35:635-637.

Morrison, R.B. and M.E. Cooley. 1973a. Application of ERTS-7 multi-spectral imagery to monitoring the present episode of accelerated erosion in Southern Arizona. Symposium On Significant Results Obtained From the Earth Resources Technology Satellite-1. Vol. 1: Sec. A. NASA, Washington, D.C. 1973.

Morrison, R.B. and M.E. Cooley. 1973b. Assessment of flood damage in Arizona by means of ERTS-1 imagery. Symposium On Significant Results Obtained From the Earth Resources Technology Satellite-1. Vol. I, Sec. A. NASA, Washington, D.C. 1973.

Poole, Donald H. 1969. Slope failure forms: their identification characteristics and distribution as depicted by selected remote sensor returns. Proceedings of the Sixth International Symposium on Remote Sensing of Environment. Vol. II. University of Michigan. Ann Arbor, Michigan. 1969.

Roubicek, C.B., R.T. Clark, R.M. Richard, and O.F. Pahnish. 1956. Range cattle production and post-weaning performance - a literature review. Agr. Exp. Sta. Univ. of Ariz. Tucson. Rep. 138.

Sampson. A.W. 1952. Range management, principles and practices. John Wiley and Sons, Inc. 520 p.

Satterlund, D.R. 1972. Wildland watershed management. The Ronald Press Co. New York. 390 p.

Seevers, P.M. and J.V. Drew. 1973. Evaluation of ERTS-1 imagery in mapping and managing soil and range resources in the Sand Hills region of Nebraska. Symposium on Significant Results Obtained From the Earth Resources Technology Satellite-1. Vol. 1: Sec.A. NASA, Washington, D. C. 1973.

Sharpe, C.F.S. 1938. What is soil erosion. U.S. Dep. Agr. Misc. Pub. No. 286.

Stoddart, L.A. and A.D. Smith . 1955. Range management. 2nd Ed. McGraw-Hill Book Co., Inc. 419 p.

Stuart, D.M., G.E. Schuman, and A.S. Dylaa. 1971. Chemical characteristics of the coppice and dune soils in Paradise Valley, Nevada. Soil Sci. Soc. of Amer. Proc. 34:607-611.

Talbot, M.W. 1937. Indicators of southwestern range conditions. Dep. Agr. Farmers' Bull. No. 1782.

Tanguay, M.G., R.M. Hoffer and R.D. Miles. 1969. Multispectral imagery and automatic classification of spectral response for detailed engineering soils mapping. Proceedings of the Sixth International Symposium on Remote Sensing of Environment. Vol. I: University of Michigan, 1969.

Tueller, P.T., G. Lorain, K. Kipping and C.Wilkie. 1972. Methods for measuring vegetation changes on Nevada rangelands. Agr. Exp. Sta., Univ. of Nevada-Reno. T16 55 p.

U.S. Department of Agriculture. 1938. Soils and men. Yearbook of Agriculture. 1232 p.

U.S. Department of Agriculture. 1951. Soil survey manual. No. 18. 503 p.

U.S. Department of Agriculture. 1959. Forest and range hydrology handbook. Forest Service.

U.S. Department of Interior. 1973. Watershed conservation and development system. BLM Manual 7322. 19 p.

Appendix 1

WATERSHED SAMPLING PROCEDURE

This section provides a guide to the obtaining of 70 mm large scale serial photography for an inventory of erosion on National Resource Lands administered by the BLM. These photographic data will also be of value in evaluating other resource management factors such as range condition and trend, off road vehicle use, wildlife habitat, recreation impact and as an aid to the development of environmental impact statements.

Pre-Flight Preparation

Three people will be involved in pre-flight preparation - 1) district representative (navigator), 2) pilot, and 3) photographer. The pilot and photographer will be working statewide and probably across several state boundaries. For this reason it is important that a local district person be involved in each photo mission. He will guide the pilot to important targets of opportunity, identify land marks, and to assist in determining that the mission is accomplished correctly in relation to local needs.

Navigator

Equipment needed:

1. Acetate overlay material
2. Rapidiograph pens (several)
3. Color or Color IR photos (1:100,000 or similar scale): to be used for site stratification
4. Topographic map with watershed boundaries outlined
5. Photo interpretation protractor for determining flight line bearings.

6. Light table if transparencies are used.

Procedure:

These procedures should be accomplished cooperatively by the navigator, pilot and photographer so that mission problems can be reduced to a minimum.

1. Identify targets, both possible opportunity and confirmed, for each watershed, through discussion with District Staff. Other opportunity targets for other disciplines will also be reviewed.
2. Outline watersheds on aerial photos and 15 minute topographic maps.
3. Stratify (type) the watersheds where not complete:
   a. Divide major landforms first, e.g., mountains, fans, valleys, playas, ridges, or slopes. The following (listed in order of importance) can also be used as criteria for further stratification: exposure, plant community or vegetation aspect, general erosion condition (SSF rating) and other categories which will serve management objectives. Each important stratification unit or different area will be sampled by crossing them with flight lines. The length of the flight lines will be relative to the percent of the total area they make up, or to the intensity of sampling that is needed.
4. Develop the flight plan on a acetate overlay of small scale photos or a topographic map using small scale photos as an aid. The usefulness of small scale photography (1:100,000

or smaller) has proven to be an invaluable aid to both site stratification and flight planning.

a. The number and location of flight lines will be determined in relation to sampling requirements associated with distribution of the various units. Also, the flight lines must be planned so that abrupt changes of altitude are not necessary.

b. The distance between stereopairs or each flight line will vary with each type. For example, on a playa where there is little variation the distance between bursts may be set at .5 miles (18 seconds at 100 mph) or more, while in the mountains where there is a lot of variation, the bursts may be spaced only .25 miles (9 seconds at 100 mph) apart.

c. Known critical areas and areas of interest should be outlined and a sampling procedure selected. The expected number of bursts can then be totaled and the amount of film to be used estimated.

d. The direction of the flight lines should be determined in cooperation with the pilot, and identified landmarks noted.

e. The suggested flight plan, with the desired altitude and desired airspeed, should be sent to the pilot and photographer for review.

5. The weather must be carefully evaluated prior to committing the pilot and photographer to several days in an area. It is

important that several days of work be available so that photo missions can be accomplished with the greatest cost efficiency.

6. Final review of flight plan. If the plane and pilot are hired at the district level, this should be the job of the navigator. However, at the state level, it can be the photographers job. The latter is probably more efficient because:
   a. not all districts have nearby flight services with properly equipped aircraft.
   b. the photographer, normally being more closely associated with planes and pilots, will have greater knowledge of specific requirements.

Photographer

Equipment:

The photographer will check and have in operating condition the following equipment and supplies:

1. Camera (currently 70 mm Hulcher Model 103, Rapid Sequence Camera)
2. Light meter
3. Intervalometer and/or stop watch
4. Camera lenses, 6" or 12" or both
5. 12 volt battery or power supply hookup with aircraft system
6. Supply of film
7. Film loading bag
8. Camera mount and small tools

Procedures:

1. Review flight plans with the following in mind:
   a. Film type - color, color IR - Color is probably best for general use, but if the use of color infrared is desired for other reasons (vegetation analysis for example) the use of color infrared does not make erosion evaluations significantly less accurate or more difficult. Color is recommended because (1) areas in shadows are more difficult to expose properly with color infrared, (2) color gives a more representative picture. When color infrared film is used, a Kodak Wratten Filter Number 12 must also be used.
   b. Altitude and scale - scale should be between 1:600 and 1:1000, therefore, with a 6 inch lens the altitude must be between 300 ft. and 500 ft. In Nevada these scales can be safely flown over most of the land areas of interest.
   c. Lens requirement (usually 6 inch lens; where altitude must be greater than 500 ft. Use 12 inch lens).
   d. Date of mission (coordinates statewide schedule). The snow must be off all areas to be evaluated, also if updating a past inventory, the mission should be accomplished as near the same phenological time as possible.
   e. Vegetation and soil types to be photographed.
   f. Considers special targets and their requirements (example

water studies must be done during early morning or late afternoon).

2. Make necessary arrangements for plane and pilot.
3. Review final flight plan with navigator and pilot.
4. Install photographic equipment in aircraft and give final check out to camera and power source. Note that the cameras must be placed so that the take up spool is toward the front of the plane.

Pilot

Procedure:

1. The pilot will be responsible for the aircraft preflight and for aircraft operation and safety.
2. Evaluate weather
3. Review flight plan and comment
4. File flight plan
5. Determine that equipment is properly placed in the aircraft.

In-Flight Activities

Navigator

Equipment Needed

1. Flight plan - map or photo with overlay
2. Clipboard, forms and note paper. (See Appendix 4).
3. Binoculars - may be useful to aid in the evaluation of erosion features particularly and to evaluate critical areas.

Procedure:

1. Accompany pilot and photographer on mission to identify flight lines, identify critical areas and opportunity targets, and to make pertinent notes. Notes will be made of time of day, weather, and any other pertinent factors.
2. Signals photographer when to activate and deactivate camera and check off each flight line and special targets as they are photographed. Makes notes about location of opportunity targets and newly identified critical areas.
3. Is responsible for seeing that all objectives of the flight plan are met.

Photographer

Equipment:

1. Same as listed above
2. Clipboard and forms to note date, film type, F-stop for each vegetation type, etc.

Procedure:

1. Sets correct exposure
2. Exposes photographs at the proper time
3. Reloads film as needed
4. Care of film

Pilot

Procedure:

1. Comply with regulations of the Federal Aviation Administration
2. Be responsible for aircraft operation and safety
3. Accurately fly recommended flight lines at the proper altitude and flight speed.

Post-Flight Activities

Pilot

Procedures:

1. Closes flight plan
2. Discusses flight plan with navigator and photographer

Photographer

Procedures:

1. Prepare film for processing and shipment to processor on a daily basis.
2. At completion of flight plan, verify contract charges and release pilot.
3. Submit voucher for payment to District Manager.
4. Discusses mission evaluation with navigator.

Navigator

Procedures:

1. Evaluates the photo mission and prepares suggestions for improvement.
2. Prepares and submits copy of evaluation report to photographer for review and comment.
3. Provide other District personnel with photos requested and opportunity photos related to their area of responsibility.

Data Analysis and Evaluation and Management Recommendations

Film Storage and Filing

1. All photographic data will be stored as roll film. The film

will be processed and made available as positive transparency prints. When each roll is received it will be given an accession number and filed at the District Office. The roll will consist of a series of two-framed stereo pairs. Each of these will be numbered for easy reference.

Appendix 2
INTERPRETATION GUIDELINES

Introduction

Interpretation guidelines cover the interpretation of 70 mm large scale (1:400 to 1:1,000) photography for the determination of the erosion condition class of arid and semi-arid lands. The author assumes that persons using these guidelines will be familiar with the use of a stereoscope, and with erosion and soil surface factors as they appear on the ground. In order that all persons making erosion estimates might do so with somewhat the same understanding, erosion and erosional terms and ratings have been defined and explained, with special reference to their detection and interpretation on aerial photography.

Erosion Defined

Erosion is the separation and transportation of soil materials. No distinction is made between geologic and accelerated erosion.

Detecting and Evaluating Erosion

Limitations of Large Scale Photography. When using large scale photography, the contrast between the background and the object or factor to be identified plays a part equally as important as the exact scale being studied. For example, in an area of very good contrast, a rill 2.5 cm (1 in) deep and a rock 7.6 cm (3 in) in diameter may be identified at a scale of 1:950; yet in an area where the contrast is poor, at a scale of 1:700; the smallest identifiable rocks and rills

might be 10.2 cm (4 in) in diameter and 5.0 cm (2 in) deep, respectively. Barbed wire strands, which have excellent contrast, were seen at a scale of 1:600, while at the same time, the larger but less contrasting fence-posts are harder to see (Fig. 1).

Fig. 1. Highly contrasting wire is easily seen. Larger fence posts, though easily identified by shadow, are difficult to see.

The very early stages of erosion (and the simultaneous downward range trend) are often evident only by careful and successive ground observations by trained observers. This, together with the limitations as discussed above, attest that identification of incipient erosion is beyond the practical utility of the 70 mm system.

Evaluating the Photography - In making the evaluations, each stereo-pair should be evaluated independently and an evaluation sheet (Appendix 5) completed for each pair. Only the actual area viewed is evaluated.

In examining a stereopair, the interpreter will find it very helpful to use a X12 monocular magnifying glass along with the X2 or X4 stereoscope.

Admittedly, an educated guess is often a part of an erosion evaluation made from aerial photography, especially at the smaller scales or when contrast is poor. For this reason, it is important that interpreters be fully familiar with erosion as it appears on the ground. By using experience gained on the ground, the interpreter is often able to accurately estimate the details of erosion by viewing the general, overall conditions seen in the photography.

Soil Surface Factor Identification and Explanation of Terms and Ratings - Sheet erosion is the more or less uniform removal of soil from the land surface without the formation of rills and gullies. The following indications of erosion are defined, identification on photography discussed, and the ratings explained. Flow pattern is the soil surface factor used to evaluate sheet erosion.

Flow patterns are the depressions which deliver surface runoff to the water channels. Flow patterns differ from gullies and rills in that they do not have sharply defined banks or sides. They can be detected on photography by some or all of the following indications: 1) In an area of very low or no erosion, flow patterns may have a lush growth of vegetation, due to the concentration of water in them. However, on sites with erosion evident, the flow pattern may have a scarcity of vegetation due to increased erosion; 2) On color infrared film, flow patterns may show up especially well for two reasons: a) soil in flow patterns (and in rills) often appear lighter in color than adjacent soil surfaces (Fig. 2);

b) the vegetation in flow patterns will often have a higher infrared reflectance due to higher soil moisture (Fig. 3). This is true in spring and early summer. 3) Flow patterns may be identified and evaluated by the following evidences of erosion, (these are usually seen in the flow patterns first) of which a, b and c are of primary importance when using aerial photos; a) deposition of silt and sand, b) terracing due to deposition behind obstacles, c) lack of vegetation, especially in the main part of the pattern, d) the development of an erosion pavement, e) the exposure of roots (not always detected on photography), f) puddling at low points in the flow pattern where the water is ponded.

Explanation of Rating - Key words are underlined

<4 - no visual evidence of erosion. The vegetation is healthy and no deposits or other erosion factors are seen.

4-5-6 - evidence of deposition or removal of soil may be seen, indicating there is soil movement (Fig. 4&5). (At scales around 1:600 or larger, terraces 1-2 inches in height may be seen.)

7-8-9 - removal and/or deposition, more than slight, but less than critical. The main portion of the flow pattern often with less vegetation than adjacent areas. Key words: moderate soil movement.

10-11-12- Soil movement appears to occur with each runoff producing event. Soil and debris are deposited against obstructions. Flow patterns contain silt and sand deposits, alluvial fans and other evidences of erosion, perhaps including the partial development of defined banks.

13-14-15- Flow patterns are becoming sharply concave, or consist of large barren fan deposits.

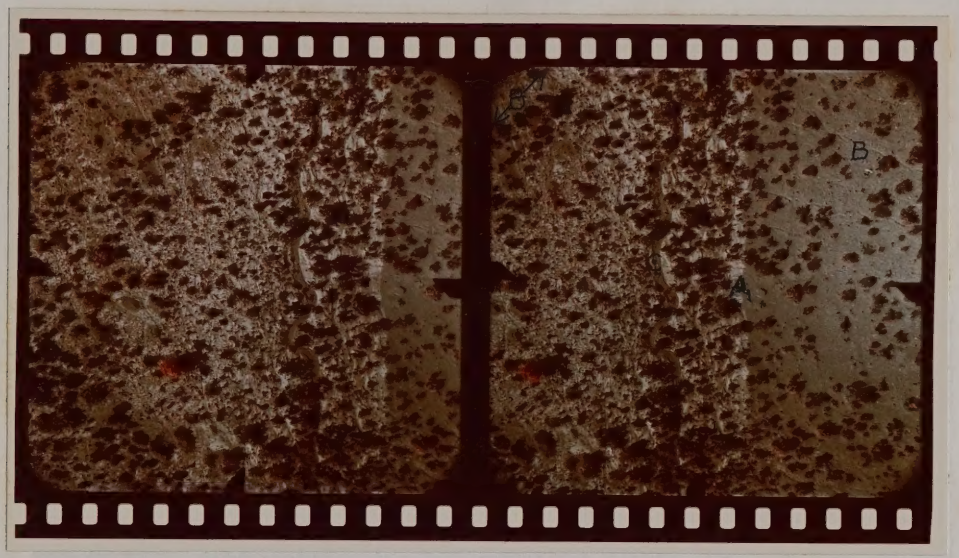


Fig. 2. A flow pattern (severe condition class) in Coils Creek watershed.
Date of photography: October 1972
Film type: Color infrared
Scale: estimated to be about 1:600
Note:

*a) lighter color of the flow pattern-probably due to the deposition of silt (A).
*b) numerous rills-both on the hillside and in the flow pattern (B).
*c) lack of vegetation and litter in the main part of the flow pattern (C).
*d) This example demonstrates the relationship between flow patterns, rills and gullies. All of the light area may be considered as within the flow pattern, and within this same area are located rills and gullies. One should realize that most of the flow patterns looked at will not be in main drainage ways and therefore will not be this large.
e) direction of flow is bottom to top
f) total SSF rating for the stereopair is in the High Moderate condition class.

*Notes with asterisk indicate notes which have bearing on the specific factor being discussed.

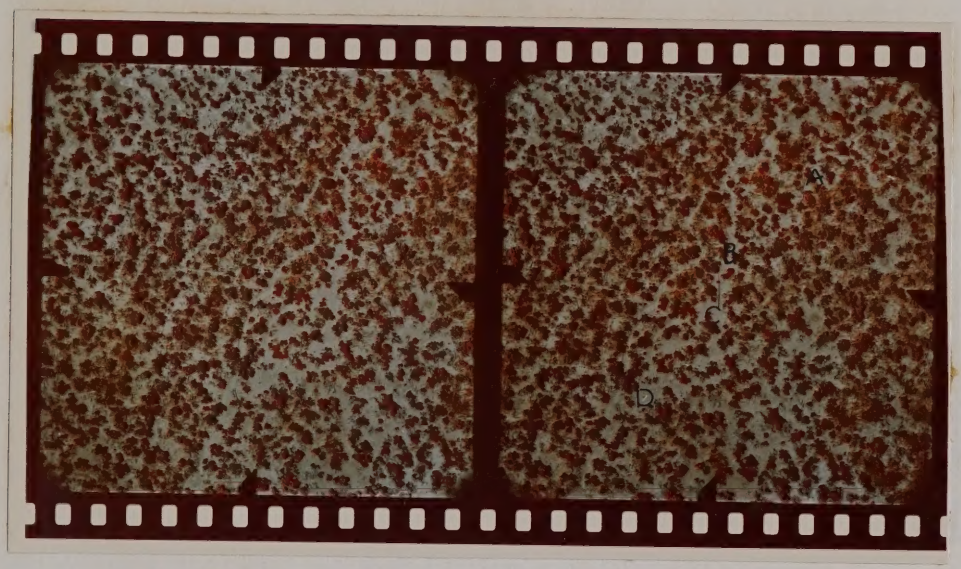


Fig. 3. A flow pattern (Moderate Condition class) in Coils Creek watershed.
Date of photography: June 1973
Film type: color infrared
Scale: 1:710
Note:

*a) though not as easily detected in the reproduction as would be in the original transparency, the flow pattern shows up a lighter color (A).

*b) Vegetation in the flow pattern have a higher infrared reflectance (B).

*c) The main part of the flow pattern has a reduced amount of vegetation and litter (C).

*d) Several deposits can be seen (D).

*e) The direction of flow is bottom to top in a left to right diagonal. Plane tilt may give the feeling that the flow is somewhat up hill.

f) Total SSF rating is in the Moderate condition class.

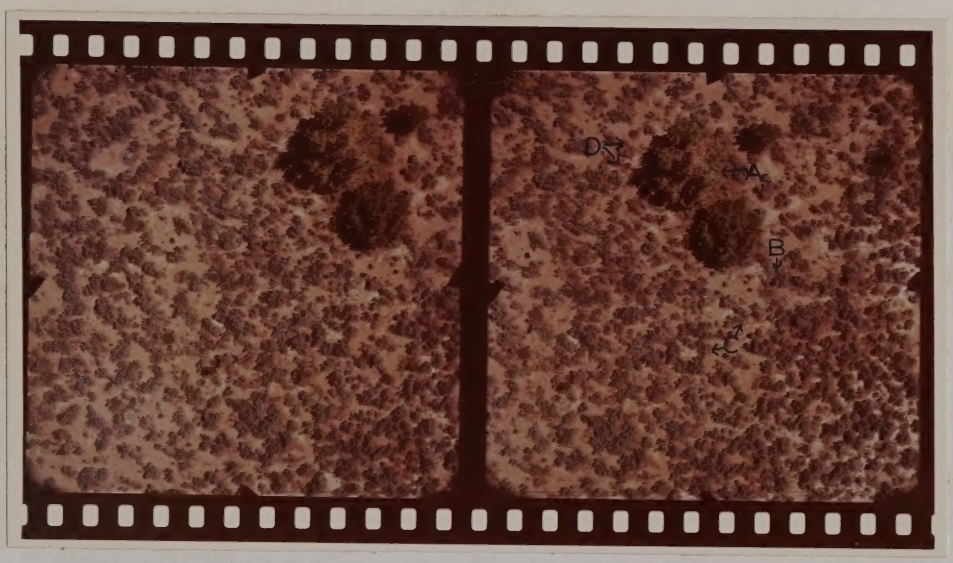


Fig. 4. Flow patterns (Slight condition class) at Hallelujah Junction
Date of photography: June 1973
Film type: color
Scale: estimated to be about 1:600
Note:

a) Juniper needles around the trees (A).
*b) terraces due to deposition behind obstacles (B).
c) spotty vesicular crusts (C).
d) most of the litter accumulation around sagebrush plants is composed of annual grasses (D).
*e) water flows from top to bottom of the photo
f) total SSF rating for the stereopair is in the Stable condition class.

Fig. 5. Flow pattern (Severe condition class) in the Coils Creek watershed.
Date of photography: June 1973
Film type: Color
Scale: estimated to be about 1:1400
Note:
*a) gully in the flow pattern (A).
b) hillside terraced due to animal trailing (B).
*c) direction of flow is right to left
d) total SSF rating for the stereopair is in the moderate condition class

Wind Erosion is the separation and transportation of soil particles by wind. There are two factors which determine the stability of an area as far as wind erosion is concerned. The first is vegetative cover (including desert lichens and moss); the second is the amount of pavement (gravel) or other rock which serves as a soil cover. It is realized that there are conditions where other factors act to prevent wind erosion, however it's questionable whether these would aid in a consistant and accurate evaluation from photography.

There are three methods of movement (Buckman and Brady, 1969) involved in wind erosion: a) creep, in which the larger soil patticles roll or slide along the ground surface, b) saltation, in which the particles move by a series of short bounces, and c) suspension, in which the finer soil particles are carried upward and parallel to the ground surface by the winds.

Deposition of soil particles occur where obstacles slow the wind down so that the soil particles drop out, or where obstacles trap the moving particles. (Soil moving by creep or saltation may be trapped by a ditch or gully.)

Keeping the above ideas in mind, consider the following ways to differentiate between wind and water erosion. 1) Soil moved by wind will move in the direction of the prevailing winds. 2) Water cuts channels; blow-outs and scoured depressions are usually oval in shape. 3) Wind deposited soil will usually have ripples on the surface which can be seen on the photography. 4) Wind drifted soil will often have a two-tone appearance. This is due to the dark colored larger particles being deposited or exposed on the windward side of the drift, and the fine lighter colored

particles being deposited on the lee side of the drift. 5) a wind drift will be steeper on the lee side than on the windward side, except in some instances where plant roots hold the soil. In such cases, the opposite may be true.

The following classification of drifts and dunes has been adapted from Melton (1940). A Dune, as used here, will mean a rounded hill or ridge of sand heaped up by the action of the wind to a height of 56 cm (two feet) or more.

A Drift, as used here, will mean a heap of soil piled up by the wind, but less than 56 cm in height.

Wind formed dunes and drifts may be classified as follows:

Barcan - an isolated bare heap of soil, crescent shaped, with the "horns" of the crescent pointing in the direction of travel. Such a drift is a sign of severe wind erosion.

Transverse - Drifts form as a somewhat evenly spaced series of long parallel ridges, perpendicular to the prevailing wind. These type of drifts are created when a large area is suddenly subjected to erosion due to loss of vegetal cover, such as may occur after a range fire. It is probable that these type drifts do not last long, and are either stabilized by vegetation, or give rise to the Barcan type of drift.

Windward - are those drifts occurring as the result of soil being piled up on the windward side of an obstacle.

Lee - are drifts and deposits formed in the lee of an obstacle or the lee side of a source (such as a blow-out or plowed field).

Shrub - coppice - are formed when shrubs trap blowing material which results in a mound forming at the base of the shrub. The coppice dune may or may not be active. A study of coppice dunes in Paradise Valley, Nevada, reported that after seven years of observation, the dunes had not moved or changed shape to any noticeable extent (Stuart, et al, 1971). Active coppice dunes may be identified by (1) scouring on the windward side and deposition on the lee side, (2) a trail of dead plant material on the windward side, the result of the plant or part of it dying as the roots were exposed by the migrating sand. Active coppice dunes are indicators of critical to severe erosion. Coppice dunes occur in all condition classes.

Blow-out - (See Fig. 6) is a depression, usually oval in shape, where the removal of vegetation has allowed a "sore spot" to develop. Wind passing over the depression creates a partial vaccuum and causes an upward swirling of air that scours out and enlarges the basin. A lee drift or dune may be deposited on the lee side of the blow-out, or soil may be carried many miles from the source before being deposited.

Explanation of Rating - It is felt that wind erosion which might occur in the stable to slight condition classes will be most effectively rated by other factors (notably bare ground and litter movement). For this reason, the wind erosion rating begins at 6. A rating less than 6 is counted as 0.

6 Bare ground is greater than 30%

7-8-9 Moderate movement is indicated by small (small means less than 20 cm (8 inches) in height) Windward drifts. There may also be some drifting or deposits in gullies, ditches, etc.

10-11-12 Coppice dunes show signs of scouring and deposition, but do not have a trail (Fig. 7). Transverse, Lee, and Blow-out drifts are small, but evident. Wind scoured depressions may be seen, but they have not eroded into the lower soil horizon. Active drifts.

Fig. 6. A large blow-out on the Blackrock Desert, Nevada. (Photo courtesy of Dr. Will Blackburn)
Note:
a) the ground covering of desert lichens and moss in the uneroded foreground.
b) erosion pavement now provides protection in the eroded area. In this case, the pavement limits the depth of the blow-out.

13-14 Any of the following may be seen: Active dunes of any kind (other than as described above), Barcan drifts; Windward, Lee, Transverse, Blow-out drifts which are active and larger than 20 cm in height; Blow-outs carved into the lower soil horizon.

Litter is the overlying layer of largely undecayed, non-living organic material which covers the soil. Large pieces, large deposits

Fig. 7. Areas of Critical wind erosion near Pyramid Lake.
Date of photography: January 1974
Film type: Color
Scale: Estimated to be about 1:800
Note:
*a) There are many active coppice dunes, but they do not have a trail, indicating that the plants are stable (A)
*b) Area of deposition (B)
*c) Scoured area (C)
*d) Wind blown litter (Russian thistle) (D)
e) Total SSF rating for the stereopair is in the Critical condition class.

or highly contrasting litter are usually easily seen. When looking for litter, consider what color it will be and where it will most likely be located. For example, in Fig. 8, look at the base of the juniper tree at A. Note the encircling dark area (don't confuse with shadow). Observe that the dark area (juniper needles) trails into the rills at B, thereby indicating litter movement. Also, movement of litter is evidenced by accumulations that can often be seen deposited against various obstacles in flow patterns and water channels or hillsides. The arrow at D points

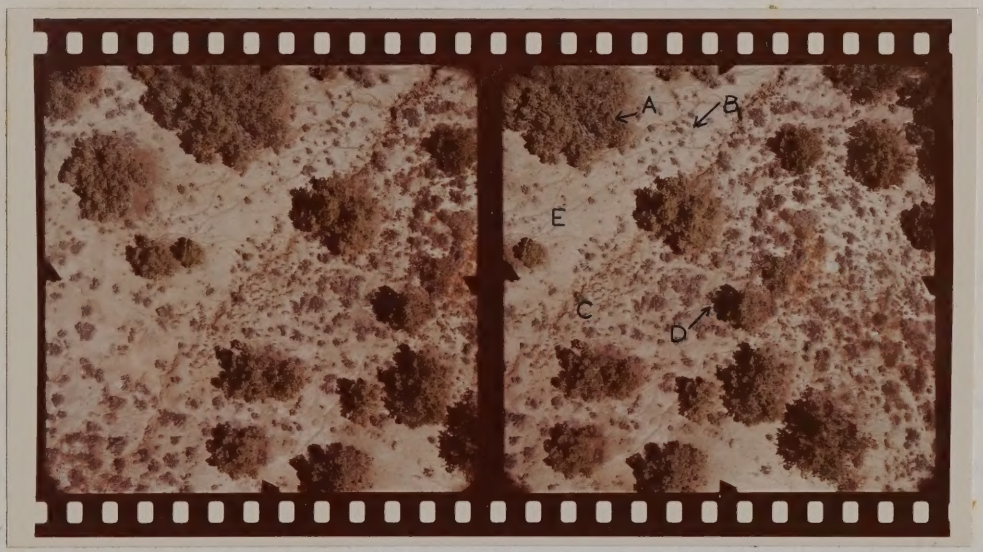


Fig. 8. Litter movement (Critical to Severe condition) at Hallelujah Junction
Date of photography: June, 1973
Film type: Color
Scale: 1:570
Note:
*a) juniper needles (A)
*b) juniper needles in rills, indicating movement (B)
c) terraces formed by deposition behind sagebrush (C)
*d) juniper log and associated litter (D)
e) most of the bare ground has a vesicular horizon (E)
f) total SSF rating for the stereopair is in the Critical condition class.

to a dead juniper log and associated sticks. Pieces of dead sagebrush can be detected at several places throughout the frame.

Explanation of Rating -

4 Litter accumulating inplace, i.e., no movement detected.

5-6 May show slight movement

7-8 Moderate movement is apparent, deposited against obstacles.

9-10-11 Extreme movement apparent, large and numerous deposits against obstacles.

12-13-14 Very little remaining (use care on low productive sites).

Percent Bare Ground/Puddling and Vesicular Horizons - As used here, bare ground is soil which from the photograph, does not appear to be covered by vegetation, surface rock or litter.

The author realizes that by this definition, what is and what is not bare ground will vary with scale, contrast, and the experience of the interpreter. In many cases, especially if the scale is too small, bare ground will simply mean the interspaces between shrubs. Despite these short comings, 'bare ground' was chosen as a soil surface factor because (1) the amount of unprotected soil exposed to the erosive elements is a major part of estimating current erosion (Branson, et al, 1972) and (2) the vertical photography allows quick and accurate estimation of the percent cover of the major protecting constituents. (The apparent bare ground being the factor counted because - hopefully - it is the smallest).

Puddling results when raindrop splash disperses the soil aggregates, with the finer silt and clay-sized particles remaining suspended in the in the standing water or puddles. When the water evaporates or

infiltrates, the particles form a layer which, upon drying, shrinks and cracks into hexigonal surface plates of the fine material (Satterland, 1972).

Vesicular horizon is a soil crust which contains many small spherical cavities (vesicles) produced by bubbles of air trapped in the soil while it is in a saturated state. (Fig. 9). This vesicular formation is often found in association with a platy structure (Fig. 9) which some authorities feel is the precursor of the vesicular formation (Miller 1971). Vesicular horizons are low in organic matter, high in silt, unstable when saturated, negatively related to infiltration rates and indications are that they significantly reduce seedling emergence (Blackburn 1973). Obviously, such conditions result in rapid runoff and increased erosion.

Vesicular horizons can usually be recognized from the air by their white color, crusted, slick appearing texture, and the absence of vegetation. Vesicular horizons may form large patches as in Fig. 10 or may occupy the whole or part of the interspaces between existing vegetation (See Fig. 8 and 11). They may also lie hidden under overlying sand which is partly the case in Fig. 4, though this usually cannot be detected from the air.

It is significant that in many areas which have vesicular horizons, especially where these horizons have developed in the interspaces between sagebrush plants, other soil surface factors which indicate erosion are lacking or are undetectable from the air as in Fig. 11.

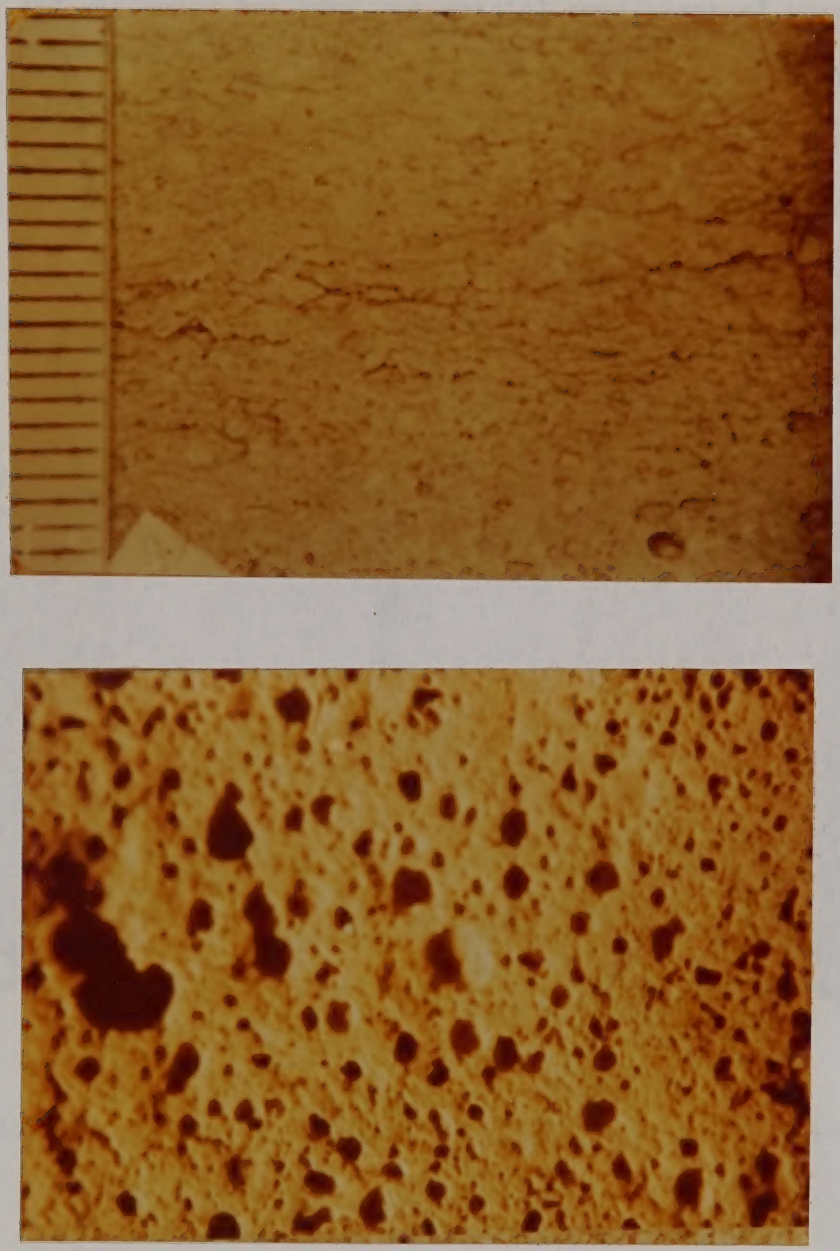


Fig. 9. Vesicular horizon showing platy structure above and vesicular pores (dark spots) in the lower photograph. Scale division is 1 mm. Top photograph is a vertical cross section, the bottom is a horizontal cross section of a different sample. (Photos courtesy of Dr. Will Blackburn.)

Explanation of Rating

Puddling and vesicular horizons are special conditions of bare ground and in effect will be rated twice. First as a condition in which the soil particles are exposed to raindrop impact, and second as a condition which contributes greatly to increased rapid runoff with little infiltration and which acts as a barrier to re-establishment of vegetation. In evaluating these conditions use a dot grid[6], 2 square inches in size with 16 dots per

Fig. 10. Patches of Vesicular Horizons-Coils Creek Watershed
Date of photography: June, 1973
Film type: Color
Scale: 1:740
Note:
*a) vesicular horizons - these patches occur on "high" ground, relative to adjacent areas (A)
b) direction of water flow is bottom to top and right to left,
c) total SSF rating for the stereopair is in the Moderate condition class.

[6]For making detailed and accurate measurements of cover, a planimeter should be used *Tueller, et al, 1972).

inch. To estimate % area which is bare ground, the dot grid is placed on one of the frames and the number of dots which fall on at least 50% bare ground are counted. The best method for doing this is a matter of personal preference. Some prefer using a monocular magnifying glass, others prefer using the stereoscope, which allows them to see "under" the dot by closing one eye. Puddling and/or vesicular horizons are evaluated at the same time. (This can quickly be done by using a tally sheet with 1 = bare ground and X = V.C. Total marks divided by total number of dots (64) = bareground. Total X's divided by 64 = \$V.C. (See Appendix 6).

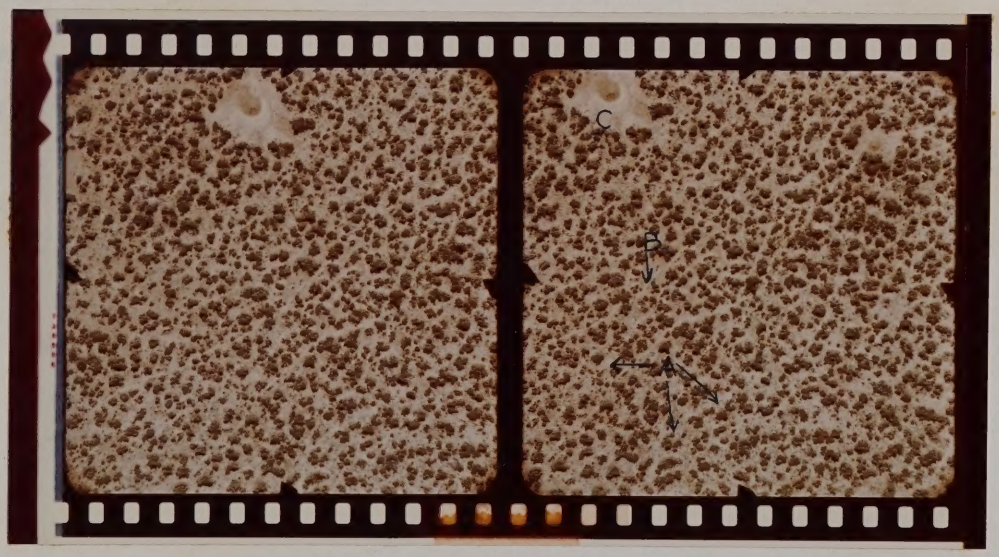


Fig. 11. Vesicular Horizon in the Interspaces-Coils Creek Watershed
Date of photography: June 1973
Film type: Color
Scale: estimated to be about 1:900
Note:
*a) vesicular crust (A)
b) cow trail (B)
c) ant hill (C)
d) total SSF rating for the stereopair is the Moderate condition class

In rating % bare ground, it is often impossible to consistently distinguish between bare ground and erosion pavement[7], expecially pavement that consists of fine gravel. This is emphasized by the average lower limit of size of rock that can be seen at various scales:

1:450----2.5 cm (1 inch) diameter
1:600----3.8 - 5 cm (1½ - 2 inch) diameter
1:850----7.6 cm (3 inch) diameter

For this reason, it may be necessary to consider erosion pavement as being a part of bare ground, except where individual rocks can be positively identified. This same consideration is generally true for other soil cover factors.

Rating - Bare ground

% bare ground	<5	10	15	20	30	40	45	50	60	65	70>	75
Rating	3	4	5	6	7	8	9	10	11	12	13	14

Rating - Puddling and Vesicular horizons

0	No puddling or vesicular horizons identified
4-5	Some puddling or vesicular horizons evident, but it covers less than 5% of the area
	Well developed vesicular horizons or puddled areas cover:
6-7	5 to 10%
8-9	11 to 20%
10-11-12	21 to 40%
13-14	greater than 40%

[7] An experienced photo-interpreter can often identify erosion pavement by (1) color (2) grainy appearance (3) location (4) association with large rock and (5) due to personnel experience on the area. However, some field checking should be done.

Gully and Rill Erosion. Water channels, whether they are perennial, ephermeral, or intermittant, often contain evidence of past as well as present erosion. This necessitates careful study of photography before a judgment is made as to the present erosion. The following are helpful in detecting current channel erosion from aerial photography:

An eroding channel will be marked by:

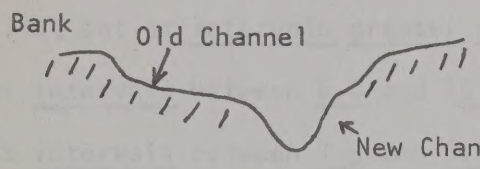
a) exposed roots of brush and trees

b) steep sides, undercut banks and/or caved-in-banks

c) lack of vegetation on channel sides and on silt-sand deposits. Vegetation in the gully bottom is not always a sign of healing or stabilization. (Ellison, et al, 1944).

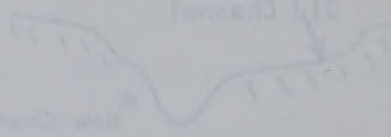
d) channel sides and silt-sand deposits have only flood deposited litter, if any.

e) a new channel with an old, as in the following diagram



Rills are small water channels formed by minor concentrations of runoff. Rills further concentrate the water, thereby increasing the erosion hazard. For our purposes, rills larger than 15 cm (6 inches) deep will be considered gullies.

A phenomenon which can be detected on aerial photography is the "fluffing-up" of soil due to periodic freezing and thawing over the winter. Such action improves the friability of the soil and causes soil sluffing



which tend to fill in rills and hide scoured appearance. A comparison of the two photos in Fig. 12 will show such a change. When evaluating photography, the interpreter should keep this in mind and ask himself if the rills will be scoured out by summer thunderstorms and, if so, how would that affect the rating?

Explanation of Rating

The erosion rating for rills will be based on their frequency (Fig. 13). The frequency measurement is made by counting the number of rills intersected along 5.72 cm (2.25 inches) of a straight edge. The straight edge is placed so as to intersect the greatest number of rills, even if only part of the 5.72 cm segment is used. Frequency estimates are made with the aid of Appendix 5. Depth and scale estimates can be made by comparing with objects of known size (see Appendix 6).

0	Unable to detect any rilling. Key words: no rills
4-5-6	Some rills, but at intervals greater than 15.20 meters (50 feet)
7-8-9	Rills at intervals between 6.0 and 15 meters (20 and 50 feet)
10-11-12	Rills at intervals between 1.5 and 6.0 meters (20 and 5 feet) per rill.
13-14	Rill at intervals less than 1.5 meters (5 feet) per rill.

Gullies and Stream Channels. The word "gully" as used here, describes the condition of a water channel and refers to large channels (for our purposes, channels which are deeper than 15 cm (6 inches) cut into the soil as a result of running water. They may develop in flow patterns, stream channels, or in soil depressions such as ruts, rills, furrows, and trails (Fig. 14).

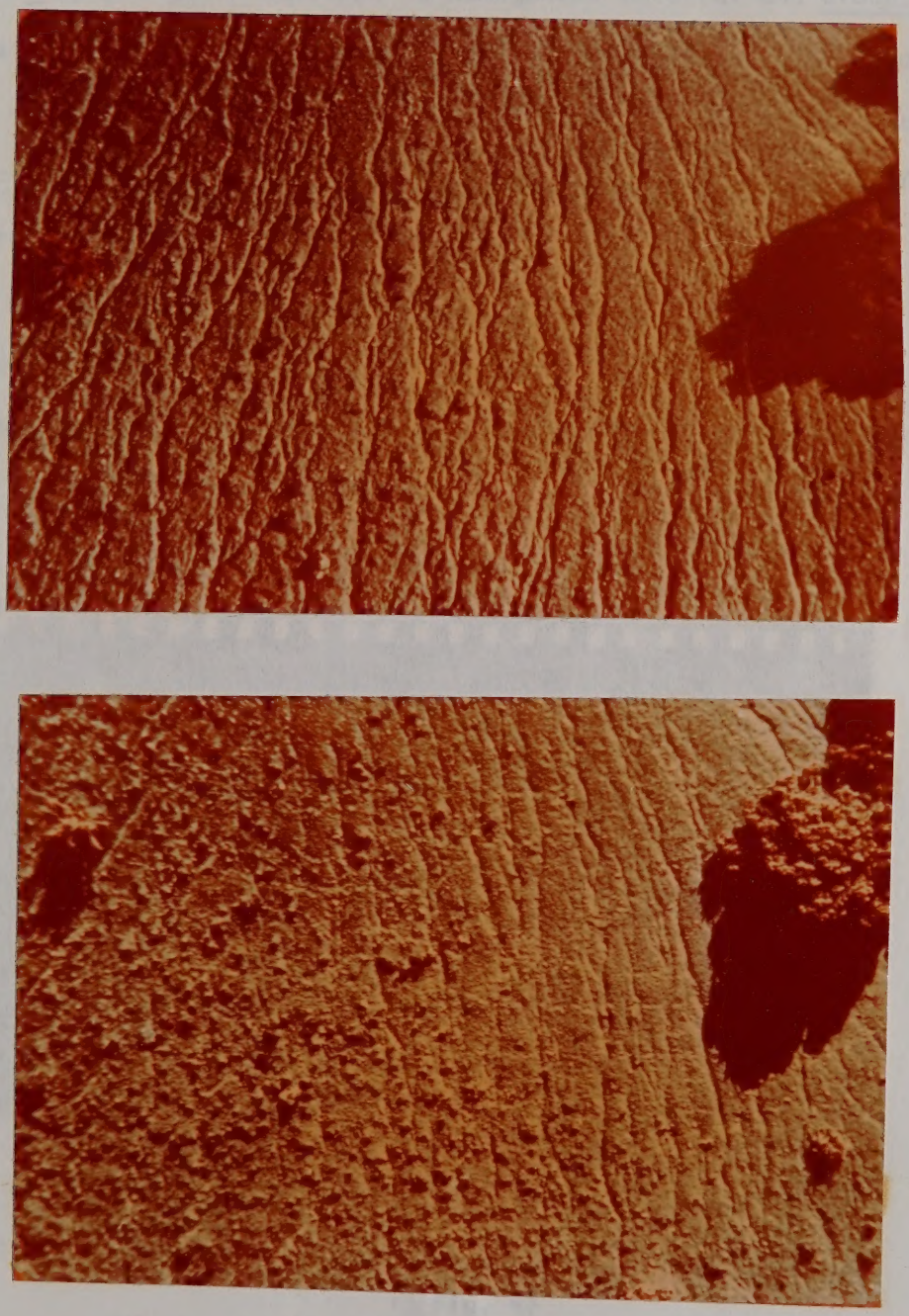


Fig. 12. A comparison of the hillside, October 1972 (above) and May 1973. Besides the disappearance of many rills, note the difference in the "texture of the soil. Film type is color infrared (Scale - 1:600).

Gullies are of two types, V-shaped and U-shaped. (Soil Survey Manual, 1951). The V-shaped gully develops in homogenous material and erodes down more or less evenly along its course. U-shaped gullies develop in soils which have an erosion resistant cover over soft substrate and are characterized by vertical sides which often undermine, causing large chunks of soil to fall into the waterway, where they are soon washed away. Gullies which develop in our mountain meadows are usually of the latter type.

As used here, "stream channel", conveys the idea of a more enduring flow of water than is found in other water channels and connotes less

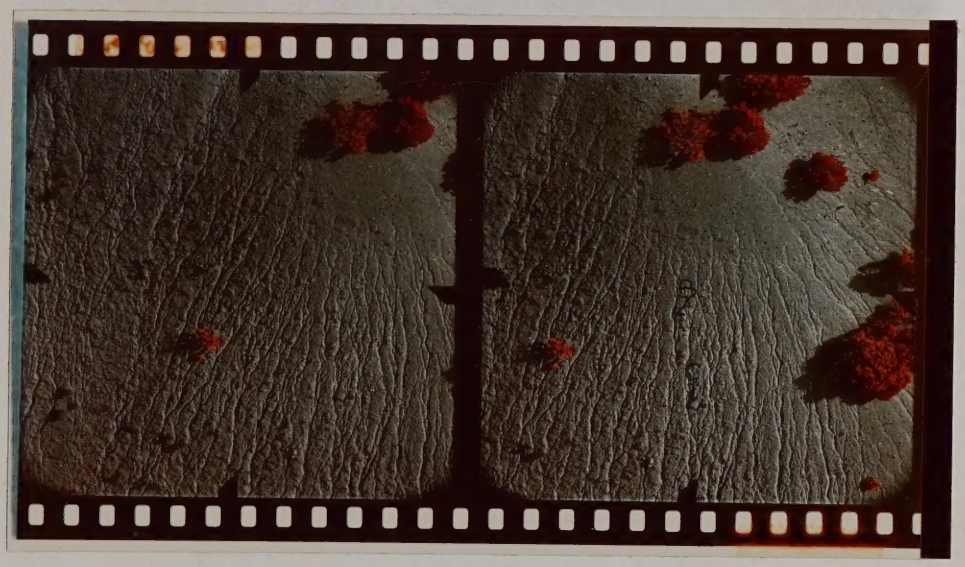


Fig. 13. Rill Erosion - Coils Creek watershed
Date of Photography: October, 1972 (compare with Fig. 4)
Film type: Color infrared
Scale: 1:645
Note:
*a) gully 18 cm (7 inches) deep (A)
*b) rill about 7.6 cm (3 inches) deep (B)
c) deposits or terraces behind sagebrush (C)
d) direction of flow is top to bottom
e) total SSF rating for the stereopair is in the Critical condition class

erosion than is suggested by the word gully. A stream channel in poor condition has a considerably higher erosion hazard than does a gully which has already devoured a meadow or worked its way down to bedrock. Stream channels are critical areas where overgrazing and/or a poor condition watershed are most likely to produce effects which can be

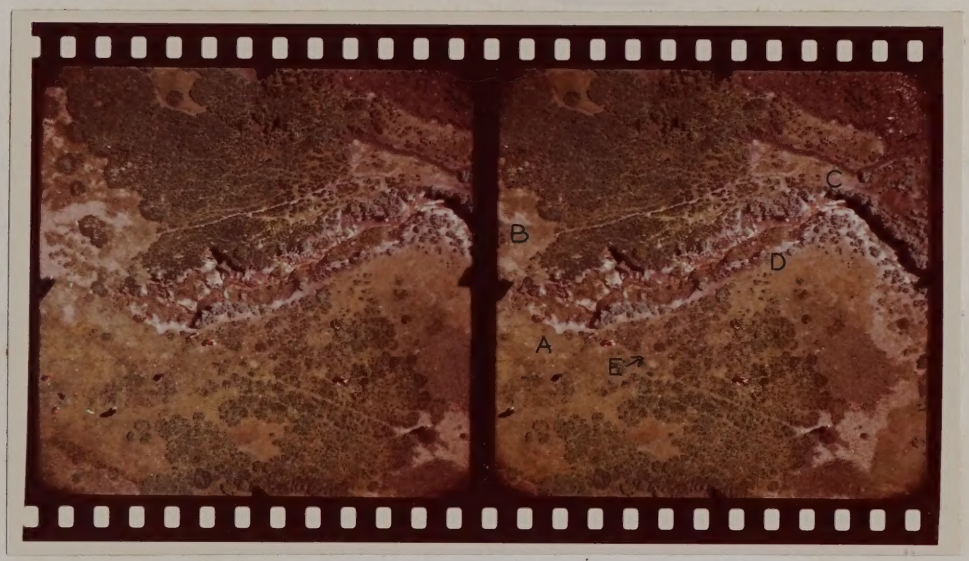


Fig. 14. A gully in a mountain meadow-Simpson Park Mountains
Date of photography: June 1973
Film type: Color
Scale: 1:1050
Note:
*a) headcut (A)
*b) soil and gravel deposited on meadow from upstream erosion. Such deposits reduce plant growth, thus preparing the way for an even greater rate of growth (B)
*c) headcutting from large gully to cowtrail, which is becoming another gully (C)
*d) straight gully walls are evidence of a headcutting gully (D)
e) cow droppings (E)
f) direction of flow is right to left
g) total SSF rating for the stereopair is in the Moderate condition class.

easily detected on photography.

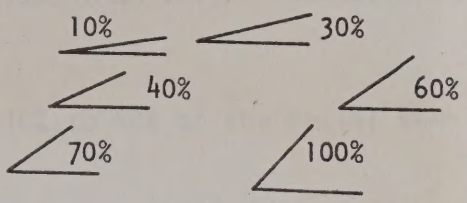
Stream channels and gullies are related in that the first often becomes the second as the result of land misuse. Also, the evidences of stabilization or of deterioration and erosion are much the same for one as for the other; therefore these two are considered together.

As an aid, the following types of channel banks are defined:

Gentle banks - 10%-30%

Moderate banks - 30%-60%

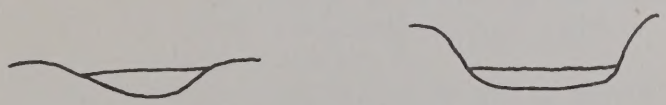
Steep banks - over 60%



Graphic presentation of slop steepness are related to percent slope (Anderson, 1972).

Explanation of Rating-

0 No gullies - stream has gentle banks as in diagram A. Compare with diagram B. Banks are well vegetated. Water, if present, is not muddy. Stream bed, if dry, is either grassy or gravelly, but not silty, i.e., no unvegetated deposits.



A B

3 Gully or gullies, if present, are in stable condition, i.e., banks are not steep and bottom and sides are well covered with vegetation and litter. Stream channels have moderate sloping banks, otherwise they are as above.

4-5-6 Gully or gullies show some recent erosion, indicated by poor vegetative cover (Figure 15), overgrazing and trampling, (Figure 16 & 17).

trailing, etc. or excess use of any kind on the associated floodplain, or (if no floodplain is evident) within 4.6 to 6 meters (15 to 20 feet) of the water channel. Stream channel-same as the description for gullies for this rating and those that follow.

7-8-9 Erosion is occurring along less than 10% of channel(s) sampled.

10-11-12 Erosion is occurring along 10% to 50% of channel(s) sampled.

13-14 Erosion is occurring along more than 50% of the channel(s) sampled.

15 Headcutting or evidence thereof is seen in the sampled areas. (This takes into account that fact that an eroding stream channel has higher erosion than does a gully.)

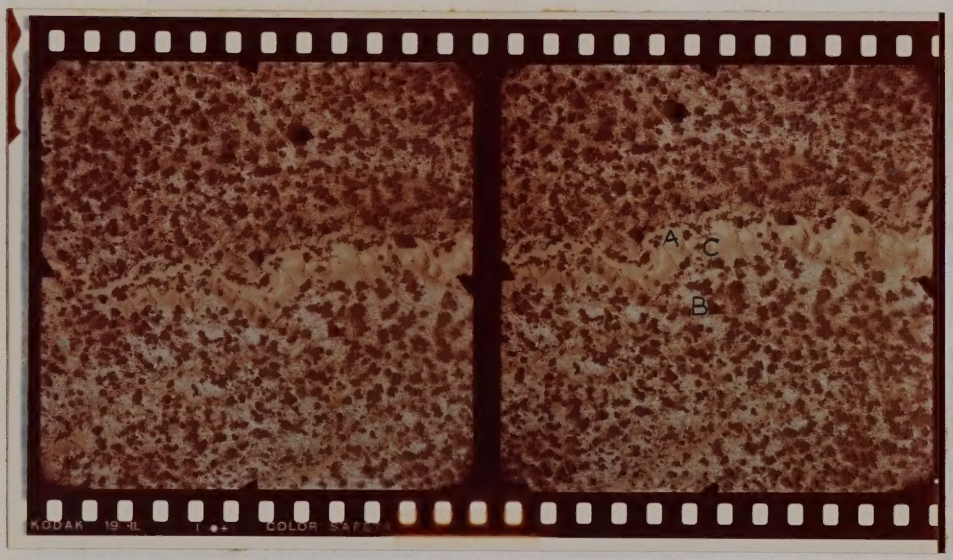


Fig. 15. Gully at Hallelujah Junction
Date of photography: June 1973
Film type: Color
Scale: 1:740
Note:

a) the white sand in the bottom of the gully vs. the vesicular crust which makes up most of the interspace between sagebrush plants (A)
b) vesicular crust (B)
*c) lack of vegetation on gully sides (C)
d) direction of flow is right to left
e) total SSF rating for the stereopair is in the high Moderate condition class

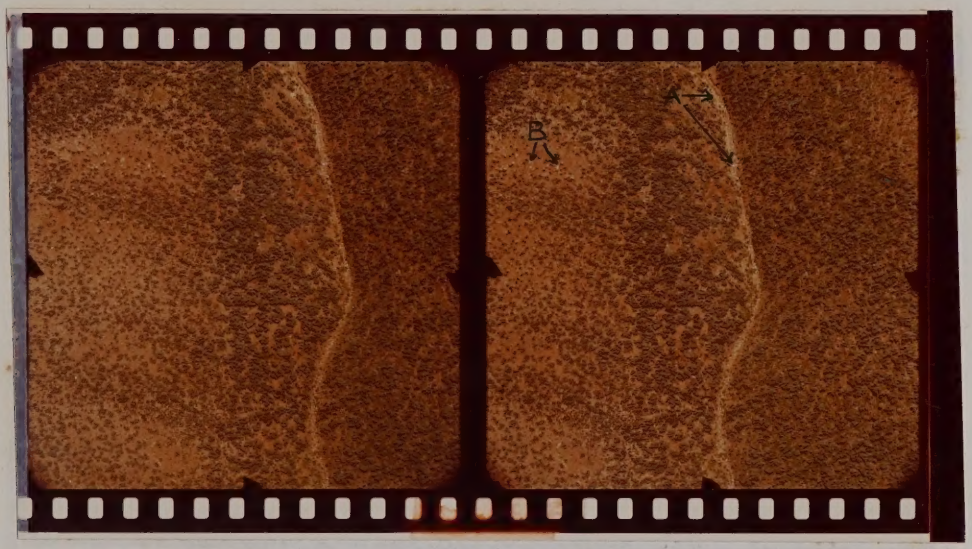


Fig. 16. Ephemeral stream - Coils Creek watershed
Date of photography: June 1973
Film type: Color
Scale: Estimated to be about 1:1500
Note:
*a) recent bank and bed erosion (A)
b) vesicular crusts (B)
c) direction of flow is bottom to top
d) total SSF rating for the stereopair is in the Moderate condition class

Fig. 17. Ephemeral stream - Coils Creek watershed
Date of photography: June 1973
Film type: Color
Scale: Estimated to be about 1:800
Note:
*a) rock in stream bed (A)
*b) eroding bank (B)
c) cow trail (C)
d) direction of flow is bottom to top
e) total SSF rating for the stereopair is in the Moderate condition class

Appendix 3
GLOSSARY

Density Slicing	The process in which a photograph is scanned by a television scanning camera which examines each part of the picture and determines its photogenic density. The electric signal from the scanner is fed through an analyzer and each different shade is color coded in sharply contrasting colors. (Edelson, 1973)
Erosion hazard or erodability	The susceptibility of soil to erosion
Erosion pavement	That layer of gravel which is left as a soil cover after the topsoil is removed by erosion. The Soil Survey Manual (1951) defines gravel as a mass of pebbles, a pebble being a rock less than 3 inches in diameter and larger than 2 mm. Fine gravel consists of pebbles less than ½ inch in diameter.
Headcutting	A process of erosion whereby a gully grows upstream through undercutting the bank and/or original stream bed. The sides are usually precipitously steep at the head and just below.
Large and small rock	As defined by the BLM Manual 7322 - Large rock is all rocks and stones have a maximum length larger than two inches on the exposed surface. Small rock is rocks and stones having a length between 1/8 and 2 inches on the exposed surface.

Recent erosion — Is defined as that occuring at the time the field survey is made. (BLM Manual 7322)

Scale — The realtion between map or photo distance, expressed as a fraction (1:600, often referred to a representative fraction or a R.F.) or as a ratio (1:750 or one inch on photo = 750 inches on the ground). Scale can be determined by the following relationships (Avery, 1968):

$$RF = \frac{\text{Camera focal length (ft)}}{\text{Altitude above the ground (ft)}}$$

$$RF = \frac{\text{Photo distance between two points}}{\text{Ground or map distance between same points}}$$

Soil Surface Factors — Surface features considered when evaluating erosion (adapted from BLM Manual, 7322).

Terracing — There are two types which we are concerned with. The first is terracing produced by deposition of silt and sand or gravel behind an obstacle in a rill or flow pattern. The second is series of trails made by animals grazing on the contour of hillsides. (See Fig. 1)

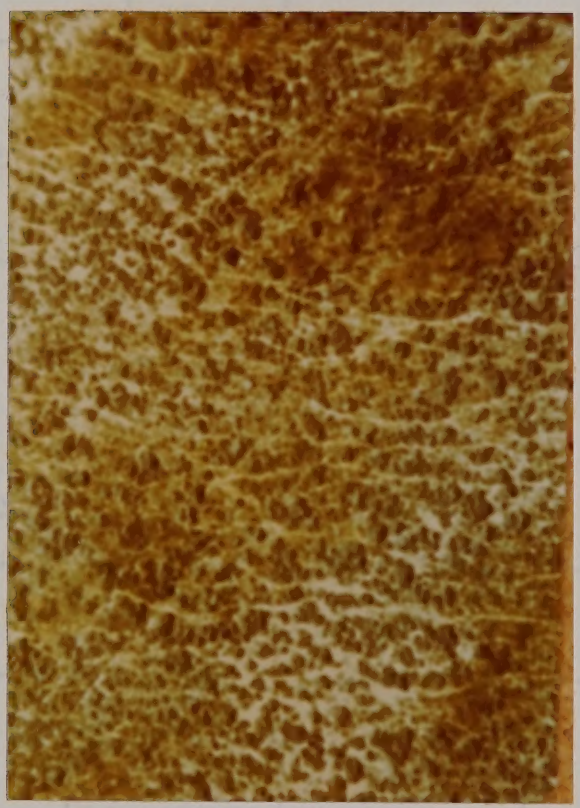


Fig. 1. Terracing due to grazing animals

Appendix 4

RESOURCE INVENTORY AERIAL DATA

Watershed-Allotment	Date	Small Scale Photo No's. & Date

I. Critical Areas

Location or Map Symbol	Film Footage	Comments

II. Systematic Survey

Flight Line no.	Type no.	Film Footage	Comments F Stop, etc.

Appendix 5

Erosion Condition Class

	Stable*	Slight	Moderate	Critical	Severe
Bare Ground	5% or less Rating 3	10 15 20 4 5 6	30 40 45 7 8 9	50 60 65 10 11 12	70 75+ 13 14
Vesicular Crust	None 0	Some present but <5% 4-5	5-10% 11-20% 6-7 8-9	21-40% 10-11-12	Above 40% 13-14
Litter	No movement <4	Slight movement 4 5 6	Deposited 7 8 9	Extreme movement 10 11 12	Little remaining 13 14
Wind Erosion		Bare ground 6	Some drifting 7 8 9	Active drifts 10 11 12	Active sand dunes 13 14
Flow Patterns	No erosion <4	Removal and/ or disposition 4 5 6	Moderate soil movement 7 8 9	Movement occurs w/ each event 10 11 12	Becoming channeled or large Barren Fans 13 14 15
Rills	No rills 0	1 interval > 50 ft. 4 5 6	interval 20-50 ft. 7 8 9	interval 5-20 ft. 10 11 12	interval < 5 ft. 13 14
Gullies and S.C.	Stable condition 3	Some erosion 4 5 6	<10% 7 8 9	10 to 50% 10 11 12	>50 Headcutting 13 14 15

*Stable - an erosion condition class of "stable", does not mean the range is in stable condition; it means as far as can be detected from the photography there is no recent erosion.
Erosion Condition Classes: Stable 0-20; Slight 21-40; Moderate 41-60; Critical 61-80; Severe 81-100

Appendix 6

INTERPRETATION AIDS

Area covered by one 70 mm frame at scales of 1:400 to 1:1000.

Scale	Length of one side (ft)	Area covered (ft^2)	% of an acre
1:400	75.00	5625.00	12.92
1:450	84.375	7119.14	16.35
1:500	93.75	8789.06	20.18
1:550	103.125	10634.77	24.42
1:600	112.50	12656.25	29.06
1:650	121.88	14854.125	34.10
1:700	131.25	17226.56	39.55
1:750	140.625	19775.39	45.40
1:800	150.00	22500.00	51.66
1:850	159.375	25400.39	58.32
1:900	168.75	28476.56	72.84
1:950	178.125	31728.52	72.84
1:1000	187.50	35156.25	80.75

Shadows

In the time it takes to photographically sample a watershed (usually about one hour), there is relatively little change in sun angle, therefore, the shadows provide a reliable indicator of compass points if the photo-interpreter is cognizant of the date and time the photos were taken.

Shadows also help to establish the location of a stereopair along a flight line, since any change of direction by the plane, results in a corresponding 'change in direction' of the shadows.

Appendix A

INTERFEROMETER AREA

Area covered by one 22 cm frame at scales of 1:800 to 1:1200

Scale	Length of one side (ft)	Area covered (ft²)	% of no area
1:800	75.00	5625.00	12.91
1:850	80.375	7139.14	16.39
1:900	85.25	8700.06	20.19
1:950	103.125	10634.77	24.42
1:1000	112.50	12656.25	29.06
1:1050	121.88	14859.15	34.10
1:1100	131.25	17236.50	39.57
1:1150	140.625	20775.39	45.90
1:1200	150.00	22500.00	51.64
1:1250	159.375	25400.39	58.32
1:1300	168.75	28476.56	65.36
1:1350	178.125	31728.52	72.84
1:1400	187.50	35156.25	80.75

Shadows

In the time it takes to photogrammetrically acquire a water-shed (usually about one hour), there is relatively little change in sun angle. Therefore, the shadows provide a reliable indicator of compass points if the photo-interpreter is cognizant of the date and time the photos were taken.

Shadows also help to establish the location of a stereo-pair along a flight line, since any change of direction by the plane, results in a corresponding 'change in direction' of the shadows.

Cow droppings

Cow droppings, which show up fairly well on photography have two potential uses: to aid in the estimation of scale and to aid in the estimation of grazing use of an area.

Carneggie (1969) noted that cow droppings ranged from 10 to 23 cm (4 to 9 inches) in diameter. Hoping to obtain a less variable figure, the author measured 15 droppings at 3 different areas and restricted the measurements to "pies" or droppings where defecation was completed on one spot. The results were as follows: mean = 26.7 cm (10.5 inches) in diameter, range = 20 to 36 cm (8 to 14 inches) diameter with 23.1 cm (9½ inches), 25.4 cm (10 inches), and 27.9 cm (11 inches) being the most frequent occuring diameters (3 each).

Julander (1955) sampled two 40.5 hectares (100 acre) crested wheatgrass pastures in Utah to determine if cow droppings could be used to determine grazing uses. He notes that 11.5 droppings per cow per day is a practical figure for western ranges, but cautions that droppings tend to be concentrated at salt, water and bed grounds.

This might be a possible method for estimating cow use on mountain meadows (See Fig. 14).

Rill Frequency Chart

Condition Class Rating		4-5-6	7-8-9	10-11-12	13-14	
Rill Frequency in feet per rill		over 50'	20-50'	5-20'	Less than 5'	
Scale	1:400	1	2-3	4-15	15	Number of Rills counted
	1:450	1	2-4	5-16	15	
	1:500	1	2-4	5-18	18	
	1:550	1-2	3-5	6-20	20	
	1:600	1-2	3-5	6-22	22	
	1:650	1-2	3-6	7-24	24	
	1:700	1-2	3-6	7-26	26	
	1:750	1-2	3-7	8-28	28	
	1:800	1-2	3-7	8-30	30	
	1:850	1-3	4-7	8-31	31	
	1:900	1-3	4-8	9-33	33	
	1:950	1-3	4-8	9-35	35	
	1:1000	1-3	4-9	10-37	37	
	1:1050	1-3	4-9	10-39	39	
	1:1100	1-4	5-10	11-41	41	
	1:1150	1-4	5-10	11-43	43	
	1:1200	1-4	5-11	12-45	45	

Quick Estimate of % Bare Ground
(Based on 2 in^2 dot grid - 16 dots/in^2)

No. of dots counted				
1	11	23	36	48--75%
2	12	24	37	49
3	---20%	25	38	50
---5%	13	---40%	---60%	
4	14	26	39	
5	15	27	40	
6	16--25%	28	41	
---10%	17	---45%	---65%	
7	18	29	42	
8	19	30	43	
9	---30%	31	44	
---15%	20	32--50%	---70%	
10	21	33	45	
	22	34	46	
	---35%	35	47	
		---55%		

Page 97--list of items likely to occur on rangeland photography

Appendix 6: INTERPRETATION AIDS

This is a list of items likely to occur on rangeland photography, which can be used to determine approximate scale or in making comparative estimates

Item	Height or Depth	Length	Width	Diameter	Other
Ant hills	up to 30.0 cm (11.8 in)[2]				
Ant hill clearings				2.7-6.1 m (9-20 ft)[2]	
Barbed wire strand				.1542-.0800 cm (.0625-.0800 in)[1]	
Cattle guards			1-lane 3.0 m (10 ft) 3.7 m (12 ft) 2-lane 6.1 m (20 ft) 7.3 m (24 ft)		
Cow trail			.35 m (1.15 ft)		Range .30-.40 m (1.0-1.33 ft)
Fence posts- above ground					
Steel	1.2 m (4 ft)[1]				Distance between posts: regular fence-6.1 m (20 ft)[1], suspension fence-30.5 m (100 ft)
Wood	1.2-1.8 m (4-6 ft)			13-20 cm (5-8 in)[1]	
Herford	at withers[3]				width of head[3]
Bull	122-124 cm (48-49 in)				27.9 cm (11 in)
Cow	122-124 cm (48-49 in)				24.6 cm (9.7 in)
					Length of head[3] 48.3-50.8 cm (19-20 in) 45.7-48.3 cm (18-19 in)
O. R. V. 's					Two distinct groups: those w/hub to hub average width of 1.2 m (4 ft), and those w/ hub to hub ave. width of 1.5 m (5 ft)
Road					
non-graded 1-lane			1.5 m (5 ft)		
graded 1-lane			2.4-3.0 m (8-10 ft)		
graded 2-lane			8.5 m (28 ft)		

[1]McNamee & Kinne, 1967 [2]Hewitt, et al, 1974 [3]Roubicek, C. B., et al, 1956

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